Industrial QUALITY CONTROL

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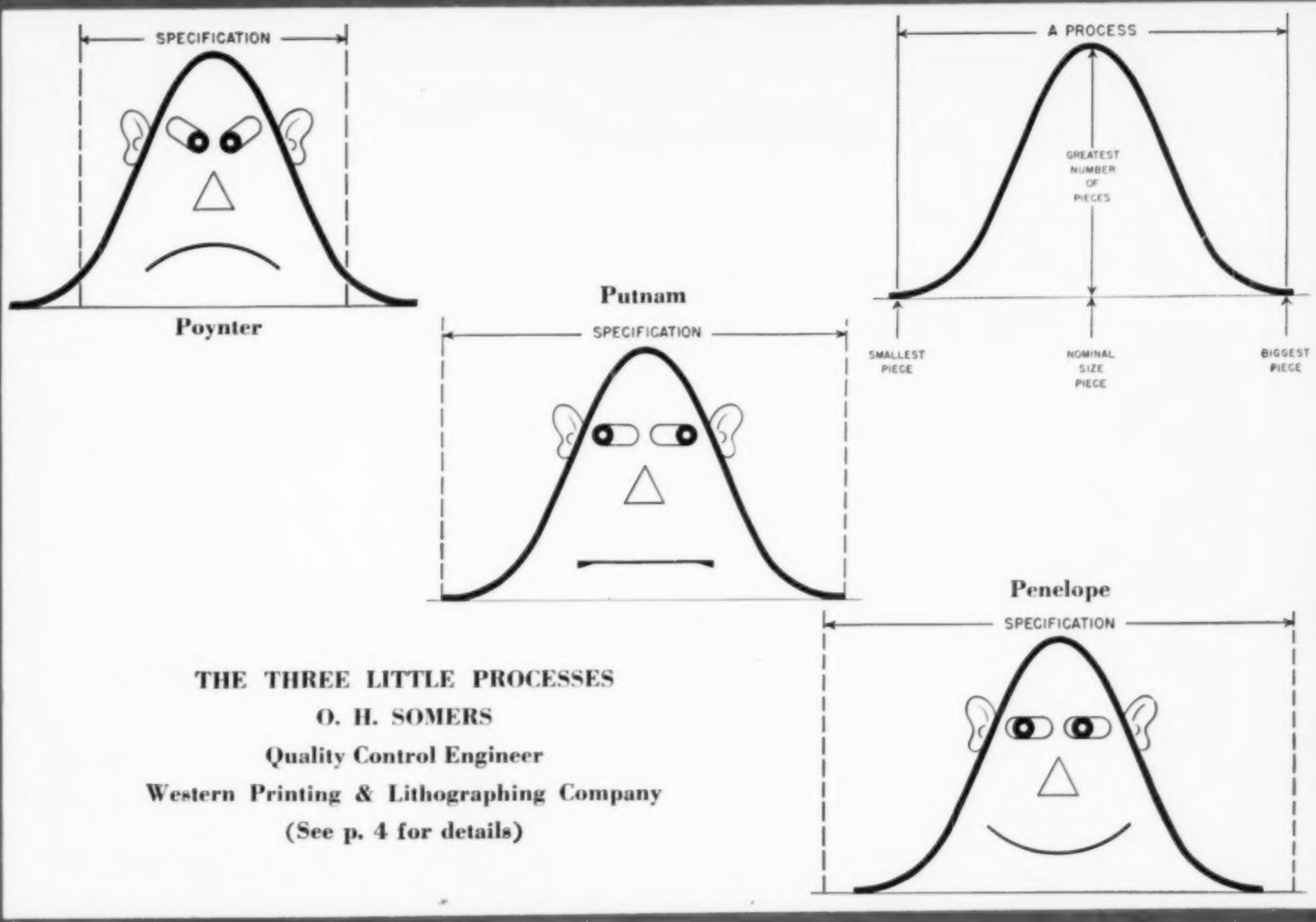

THE THREE LITTLE PROCESSES

O. H. SOMERS
Quality Control Engineer
Western Printing & Lithographing Company

(See p. 4 for details)

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THE THREE LITTLE PROCESSES

O. H. SOMERS

(See cover page picture)

EVERY time you as an engineer establish the dimensional tolerance limits on a piece your company is going to manufacture, you are establishing the boundaries within which some poor, innocent production process must live. Processes have very delicate constitutions and are quite sensitive about their relationships with both operators and engineers. Especially with engineers, however, because engineers are *much* more likely to do things which violate a process's sense of righteousness. The sketch at the upper right is one way of portraying one of these little processes, revealing it as having a bell shaped curve, the most interesting features of which are pointed out by the little notes. Observe that the most significant detail of *any* process is how *wide* it is, as shown by the arrows and phrase "A Process".

Look at Poynter, a mean, ornery, frustrated process who has never, never met an engineer. And what is more important, *his* engineer has never, never met him. Because his engineer didn't even know Poynter existed, he assigned Poynter a living space called "Specification" that just simply isn't big enough. This makes a mug-wump out of Poynter, because his mug is sticking out one side and his wump is sticking out the other! And no matter what he does, the situation gets worse. If he pulls in just a little bit of mug, a whole lot *more* wump will slip out the other side. So Poynter is *very, very* unhappy.

Then we have Putnam, a nervous, irritable type. *His* engineer knew he was around, alright, but his engineer was a rigid disciplinarian who thought little processes should not be permitted to move about with any freedom whatever. He assigned Putnam a space in which to live which was just barely wide enough. So Putnam is going through life afraid even to sneeze for fear his wump will stick out and expose that horrible social error, defects. Poor Putnam has one eye on the upper specification limit, the other on the lower specification limit. He feels *very* grim about it all.

Finally, there is Penelope, a happy, cheerful, *beautiful* little process. Her engineer fell in love with her at first sight and has given her every consideration since. He didn't give her *too* large a house, for that would have been uneconomical. And Penelope's offspring would have varied too much in size to be the most acceptable social types. No, this engineer made Penelope's house just about 1.33 times as big as Penelope herself, which is *just* right. So Penelope is a very happy little process who goes on day after day producing the *most* desirable kind of children.

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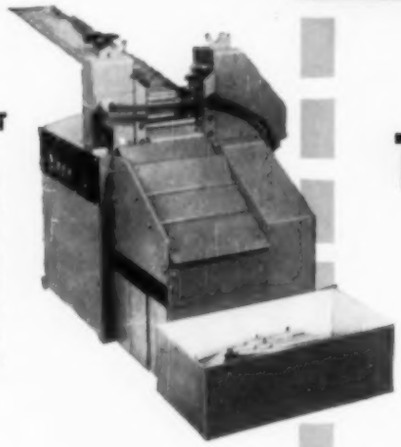

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Balancing and Randomizing In Experiments*

WARREN R. PURCELL

Manager of Quality Control, Lighting Division, Sylvania Electric Products, Inc.

INTRODUCTION

The modern quality control engineer is a vital cog in the wheels of today's industry. His services have become all-important in the ever-present problem of identifying, eliminating, and preventing the causes of excessive variability in manufacturing. By the judicious and skillful use of various statistical and graphical tools, such as histograms and control charts, he has been able to help substantially in identifying causes which elude identification by old-fashioned methods.

Occasionally, however, he has encountered difficult problems of cause identification, especially in the more complex and technical processes. The solutions of such problems often require full-scale engineering investigations. In the early days of modern quality control, such investigations were considered a separate problem to be solved by Material and Process Engineering. It is now realized that the quality control engineer has at his command additional statistical and graphical tools, such as variance analysis and correlation, to assist materially in the interpretation of the data yielded by engineering investigations.

A necessary requirement for the effective use of these specialized tools is a "way of thinking" in terms of variability and probability. Herein lies the real value of the modern quality control engineer. Because of his way of thinking, his services are valuable not only in the interpretation of data from experiments, but also in the planning and executing of the experiments themselves. Thus his usefulness is now extending beyond the problems of day-to-day process control, important as they are, to the fields of research, development, and design. Extraneous causes of variability not only disturb established processes, but also enter into experiments and often make the results tell costly lies. The fallibility of human beings and the perversity of inanimate objects are constantly rearing their heads to plague the investigator. The quality control engineer is, in many cases, the one person in the organization fully trained to cope with these intruders.

FALLACIOUS PROCEDURES

One of the most troublesome of the perversities of inanimate objects is the tendency of true causes to disguise themselves and to try to appear as something else. Consider a few illustrations.

Not long ago a packing engineer devised a new package for a certain product. Adoption of the new package would have saved several thousands of dollars annually. Before final adoption a transportation test was run to indicate whether the proposed packing would properly protect the product. In the test 1000 inspected units were shipped on a round trip in the proposed packing and 1000 inspected units in the standard packing. Upon their return they were again inspected. In the standard packing one unit was found to be defective; in the proposed packing 10 units were defective. The decision to forego the contemplated saving had almost been reached when it was pointed out that the defects could have been due to weakness in the product rather than to inadequate packing protection. Further investigation disclosed that this was actually the case, and that the proposed packing could, in fact, be adopted. The lie told by this experiment could have cost thousands of dollars.

At another time an engineer ran a test to determine the relative strengths of lamp filaments made from two different types of tungsten wire. To test the strength, 20 lamps were manufactured using one type of wire, and 20 using the other type. The lamps were then put through a standard "bump" test to determine the relative percentages of filament breakage which would result. In this test the glass bulb occasionally shatters and spoils the test of one of the lamps. But in this particular test, a strange result happened. Of the 20 lamps made with one type of wire, none of the bulbs shattered; of the 20 lamps made with the other type, 10 of the bulbs shattered. The conclusion indicated was that one type of wire caused brittle bulbs. The lie told by this experiment was so ridiculous that it fooled no one. There was, therefore, little lost in this case, unless we count the time, effort, and material expended, plus the loss of faith by the engineer in experimental results in general.

Another case is of a somewhat more familiar type. The life of a particular size of lamp was running shorter than its design called for. A suspect was the speed of the sealing machine. An experiment was therefore run in which lamps were manufactured both at the standard speed and at a slower speed. Life tests were completed, and the lamps made at the slower speed had substantially longer life. Even though it meant a loss in production, the anticipated increase in life was important, and the machine speed was therefore reduced. Unfortunately, the life remained just as it had been at standard speed; nothing was gained when the speed was reduced in actual production. The lie told by this experiment cost about ten thousand dollars in lost production, and the problem of short life remained unsolved.

These are actual cases from our files. Others could be cited. Such cases indicated to us the existence of serious fallacies in our procedures. If such obviously erroneous conclusions could be drawn, in how many cases were less obvious, but no less costly, wrong decisions being made? Every decision which is based on experimental evidence is exposed to this same hazard. What can be done about it?

*Presented at the Fourth Annual Convention, ASQC, and Fifth Annual Midwest QC Conference, Milwaukee, Wis., June 2, 1950.

Mr. Purcell is now Quality Control Manager for the Brown Company, Berlin, N. H.

QUANTITY OF EVIDENCE

One approach is to require that every important experimental decision be based on a large *quantity* of evidence. "Can you repeat the experiment (several times, perhaps) and keep getting the same result?" is the question often asked by one who uses this approach. Perhaps the suggestion is made to "try it in actual production and see what happens". But these procedures can be costly. If they produce positive evidence, they may be well worth while. But often the results become conflicting and inconclusive. A relationship that is established by today's experiment does not hold tomorrow. Engineer Smith finds that an increase in furnace temperature at a certain process stage will yield a more wear-resistant surface, but Engineer Jones finds that such a temperature increase is without effect on surface condition, or even makes it less wear-resistant. Such conflicting evidence is caused by the same kind of faulty procedures that make the individual experiment tell such costly lies. Causes not only try to disguise themselves, but they sometimes hide completely, and at other times come into full view, all with a bewildering sequence of unpredictability.

CONTROL OF CONDITIONS

A more satisfactory approach is to seek *quality* of evidence rather than mere *quantity*. Traditionally, quality of evidence has been sought by controlled conditions, in order to reduce the effects of extraneous causes. Controlled conditions, however, are elusive. No one can ever be sure just how well-controlled they are for any one experiment. In many cases control of conditions begs the question, for control is often the very objective of the experiment. In other cases control of conditions is properly challenged on the ground that an artificial "laboratory" result will not necessarily hold true in the everyday "factory".

In field tests, such as the transportation test cited, conditions are practically uncontrolled. This is as it should be. Careful execution of the test to avoid severe handling, for instance, would itself vitiate the test, for the objective is to study conditions as nearly as possible as they will be expected in practice. In factory tests, conditions are usually somewhat controlled, for this is, or should be, the normal factory situation. In laboratory tests, conditions are usually as closely controlled as the existing facilities and abilities will permit.

These various degrees of control affect the well-known "experimental error". Other things being equal, closer control means less experimental error. This has long been recognized. It has also been recognized that experimental error tends to obscure the result. What has often been overlooked is that obscuring of a result is only a small part of the havoc which can be wrought by extraneous causes. The results of the transportation test were not obscure; they told a clear lie. The bump test result was not obscure; it was ridiculous. The result of the machine speed test was not obscure; it told a ten-thousand dollar lie.

THE NEW TECHNIQUES

Obscurity can be reduced by control, but often at the price of using a narrow and misleading set of artificial conditions. Even close control, however, does not remove the possibility that clear lies will be told by the result. These lies can be adequately prevented only by one or both of two additional techniques. One of these is "balancing"; the other is "randomizing". By means of *balancing*, the possible effects of *selected* extraneous causes are *separated* from the effects of the cause or causes being investigated. By means of *randomizing*, the possible effects of *all other* extraneous causes are *neutralized*. Furthermore, these techniques accomplish these ends whatever the degree of control.

TRANSPORTATION TEST

Consider the transportation test. This test had been executed by shipping all of the 2000 units in one truck. All of the 1000 units shipped in standard packing, however, had been manufactured on one day; all of the 1000 units shipped in the proposed packing had been manufactured on a different day. The conclusion that the proposed packing was inferior was therefore without sound basis. The effects of any possible differences between manufacturing dates had been completely confounded with any difference in the effects of the two types of packing.

Questioning revealed also that no thought had been given to randomizing the order of loading the packages into the truck, handling them at destination, etc. Thus it was not unlikely that severity of treatment, as well as a difference between manufacturing dates, could also have been badly confounded with any effects of the different types of packing.

It is clear that if all 2000 units had been manufactured on one date instead of two, there would have been no confounding of effects of type of packing with effects of differences *between* manufacturing dates. There would, however, have been a narrow base for the experiment. If a difference between manufacturing dates had existed, then conclusions valid for one date would not necessarily have been valid for another date. In any case, an experiment based on one date is incapable of shedding any light on differences between dates.

Confounding of between-date effects could have been avoided and the two dates still included in this instance by an extremely simple plan of balancing.

In each type of packing, there were 100 units to the package. There were, therefore, 10 packages of standard packing and 10 packages of proposed. A simple balanced set for the experiment would therefore consist of:

5 packages (500 units) standard packing, manufacturing date I;
5 packages (500 units) standard packing, manufacturing date II;
5 packages (500 units) proposed packing, manufacturing date I;
5 packages (500 units) proposed packing, manufacturing date II.

Such a set would have balanced the effects of manufacturing dates and types of packing, and these two effects could have been separately analyzed, each without any confounding due to the inclusion of the other.

There might, however, have been other effects *within* the transportation trip and *within* each of the manufacturing dates which could also have confounded the results.

Suppose, for instance, that all 10 packages of date I had been placed at the front of the truck and all 10 packages of date II at the rear; or, probably worse, suppose that all 10 proposed packages had been in a lower layer of the loaded truck and all 10 standard packages in an upper layer. In either case any differences in transportation severity due to these locations would have been confounded with the effects which were being investigated.

It is clear that if the packages had been loaded on the truck in a truly random order, the placing of all of the proposed packages in a lower layer and all of the standard packages in an upper layer would have been extremely unlikely. So would *any other* loading arrangement which could cause a severe confounding of the results, such as the placing of all proposed at the front and all standard at the rear; always stacking proposed on proposed, standard on standard; placing a large number of one type along a diagonal of the load, etc. It is impossible to name all the conceivable reasons for bad confounding, but they are *all* removed from likelihood by the simple process of true randomizing.

Again, suppose that manufacturing conditions had changed appreciably during a day; e.g., that product made in the latter part of the day was less shock-resistant than that made earlier in the day. Suppose, furthermore, that the 1000 units selected for standard packing had been made in the early part of each of the two manufacturing dates, while the 1000 units selected for proposed packing had been made in the latter part of each of the two manufacturing dates. In such a case also the experiment would have been confounded, and in the analysis this difference, really due to manufacturing conditions, would have appeared as evidence that the proposed packing was inferior.

Again it is clear that if the units for the proposed and standard packing had been selected from the production flow by a truly random method, it would have been extremely unlikely that the assignment of units to type of packing would systematically follow fluctuations in manufacturing conditions to an extent which would cause severe confounding.

THE FALLACY OF ALTERNATING

Some experimenters attempt to circumvent the problem of randomizing by alternating, on the assumption that such a procedure accomplishes the same thing. Reflection, however, indicates that this is not so.

Consider, first, the truck loading. Suppose that the 20 packages were placed in the truck in two layers, each consisting of two rows of 5 packages. A normal way to pack such a load might be to place packages in some order such as indicated

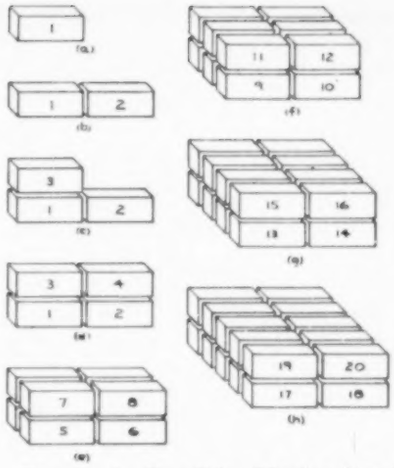

Figure 1—**Possible Methodical Loading of a Truck**

in Figure 1. If, in this sketch, the observer is looking toward the front of the truck, the packages would be placed in this order:

First package: front, left, lower
Second package: front, right, lower
Third package: front, left, upper
Fourth package: front, right, upper
Fifth package: second from front, left, lower

• • • • • •

Eighth package: second from front, right, upper
Ninth package: third from front, left, lower

• • • • • •

Twentieth package: fifth from front, right, upper

If, now, the loading is done by "alternating" in the following order:

standard date I
standard date II
proposed date I
proposed date II
standard date I

• • •

etc.

all of the standard packing will find its way to the lower layer, and all of the proposed to the upper; all of date I will be at the left, and all of date II at the right.

Consider, second, the selection of units for the proposed and standard packing. Suppose that units are selected as they come along a conveyor fed by a machine. Suppose further that alternating is done by assigning the first unit to proposed, second to standard, third to proposed, etc.

Such a machine might well have an even number of heads. Suppose that there are 10 heads, and that head number 7 is making a weaker product than the rest. The units made on head number 7 will all find their way into one type of packing. Which one, of course, will depend on when the selection starts. In either case, however, there would be severe confounding of this manufacturing fault with the effect of type of packing.

PLANNED RANDOMIZING

Usually randomizing cannot be accomplished by the simple expedient of issuing instructions to "load in random order" or the like. If, for instance, in the truck loading case discussed, the standard and proposed packages were different in appearance or had been externally identified for the purpose of the test, the shippers would have been quite likely to load first all of one group, then all of another, etc.; for the simple reason that they would want to keep track of what they were doing.

It is far safer to do intentional and planned randomizing. In this case, for instance, a card drawing scheme would be applicable. This could be carried out by assigning to each of the four groups one of the four suits of a standard deck of cards, for instance:

standard, date I—clubs;
standard, date II—diamonds;
proposed, date I—hearts;
proposed, date II—spades.

If, now, 5 cards of each of the four suits are selected, these 20 cards could represent the 20 packages. After thorough shuffling, these cards could then be drawn in random order, and numbers assigned to the packages in the order in which the cards are drawn. During the card drawing the assigned numbers (from 1 to 20) would be clearly marked on the outside of the packages and the order of drawing recorded and preserved for subsequent identification. Then the shippers and all others who handle the product would be instructed to handle "in numerical order".

THE VALIDITY OF CONCLUSIONS

After the test had been completed, the results could then be conveniently tabulated by recording the number of defective units in each of the 20 packages, tabulated by groups. This is indicated in the results of an actual test, very similar in nature,

and carried out by a similar plan of balancing and randomizing. The final data were tabulated thus:

	Date I	Date II	Total
Standard	0	0	8
	2	0	
	1	0	
	1	1	
	3	0	
Proposed	2	1	10
	0	0	
	2	0	
	1	1	
	2	1	
Total	14	4	18

In this case it was nearly evident from the raw data that a real difference between manufacturing dates had been shown, while no real difference had been established between types of packing.

A statistician, called in at the end of the experiment to analyze these data, would have reached substantially the same conclusions, except that he would have been likely to express them more cautiously. He might have said, for instance, that the indicated difference (8 and 10) between types of packing could easily have occurred by chance. He would also have said that the *indicated* difference (14 and 4) between manufacturing dates is greater than could reasonably be due to chance acting alone. It would also have been apparent to him that this indicated difference could not have been due to type of packing. For type of packing was a selected cause which had been separated by balancing. Even if a difference in effect between types of packing had existed, it could not have vitiated the comparison between manufacturing dates, because there were the same number of units of each manufacturing date in each type of packing.

The statistician's cautious statement that the "indicated" difference between manufacturing dates appears to be real; i.e., must in part at least be due to causes which did not follow the laws of chance, would have been about as far as he could go. He could not have stated that this difference was due to manufacturing conditions; i.e., existed in the product before the transportation test. For the cause "other than chance" which was responsible for the observed difference might, as far as he knows, have been due to peculiarities in the test.

But the engineer who conducted the test knew that this could not be so. He knew that his planned randomizing had made every set of causes, except two, follow the laws of chance. Those two are the types of packing and the manufacturing dates. Since the effect of type of packing had been separated by balancing, there remained only one set of causes which could reasonably have had an effect "other than chance". That cause was the difference between manufacturing dates; i.e., it had existed in the product before the test was made, and was due solely to the conditions of manufacturing.

Note that balancing works both ways. The experiment was planned to study the comparative effects of the two types of packing; the between-date difference was simply a possible extraneous effect which had been balanced to avoid confounding the main effect. As it turned out, the "extraneous" effect was the real one. This real effect was, in turn, kept free of being confounded by any difference which might have existed between the effects of the types of packing. This would not have been so if the number of units of each date's manufacture in each of the two types of packing had been unequal.

In the original experiment, in which the two effects were confounded, and from which erroneous conclusions had thus been drawn, easy essumptions had been made. By implication at least, it had been assumed that any differences in strength of product due to time-to-time changes in manufacturing conditions, and any effects due to differences in severity of treatment, were small enough to be disregarded. But those assumptions were opinions. After the experiment had been completed, the conclusions drawn had depended on those opinions; the facts had not spoken for themselves.

FILAMENT TEST

Consider the test of filament strength and its strange result of 10 shattered bulbs with one type of tungsten wire and none with the other. The tester suggested that a chip of glass must have become embedded in the bump pad during the course of the test. The fact that this explanation was offered was itself evidence that all of the lamps of one group had been tested first, then all of the lamps of the other group. Perhaps, therefore, it was sheer good fortune that the bulbs did shatter. For if a small chip of embedded glass can have such a marked effect on bulb breakage, certainly there are countless other possible time-to-time variables in test equipment and procedures which might have affected the test of the filaments even if the bulbs had not broken. Such variables would have vitiated the results anyway, and comparisons between types of tungsten wire, the very purpose of the test, would not have been valid.

Since these time-to-time variables are entirely unknown and cannot be enumerated, their effects cannot be balanced. They can, however, be neutralized by randomizing. In this test randomizing would have been extremely simple. If the tester had tested one lamp at a time, and determined by, say, the drawing of cards, from which group the next lamp should be selected, the test itself would have been completely randomized.

In this case, however, randomizing of the test would not of itself have provided a sound basis for valid conclusions. The test was a test of wire, and the wire had been through many processes before it had become filaments mounted inside incandescent lamps. To enumerate only a few, there were coiling, annealing, treating, sintering, mounting, sealing, exhausting, and flashing. Since any one of these processes *could* have affected filament strength, its effects could become severely confounded with differences in the original wire itself unless they also were neutralized.

Consider, for instance, the mounting process. Several sources of variability can be named; countless others must exist. Among the namables are the tightness of clamping of lead wires to filaments, the spacing of the supports, the tension of the filament, etc. Suppose that during the mounting of the test filaments the tightness of the clamping had been progressively increasing. If, then, all 20 filaments of one group were mounted first, and all 20 filaments of the other group afterwards, any effect of clamping tightness would vitiate any conclusions about type of wire. If, however, the order of feeding filaments to the mount machine had been randomized, any effect due to clamping variables

would have been neutralized and would not have vitiated the conclusions.

Before the experiment had been started, or during its execution, it would have been easy to assume that the effects of clamping tightness were either non-existent or small enough to be disregarded. But such an assumption would have been an opinion. After the experiment had been completed, the conclusions drawn would then have depended on that opinion; the facts would not have spoken for themselves.

Once the specimens of wire, the difference between which was to be tested, had been selected, they should then have been sent through every subsequent process, including the test itself, in random order. It is clear, however, that the mere feeding of units to a machine in random order will randomize every step of the process which is performed by that machine; and the introduction of the units to any series of processes in random order will randomize every one of the processes, provided the units are not sorted into order between processes.

MACHINE SPEED TEST

Consider next the machine speed test. It was apparent to one and all that "something else", other than machine speed, must have entered into the experiment to give the definite evidence of longer life at the slower speed. Many are of the opinion that those "something elses" are simply the perversities of nature to which experimenters must become resigned unless they are willing to repeat their experiments several times and make no decisions unless consistent results can be shown.

To those who have formed the habit of thinking in terms of variability, however, such a result was not surprising. Every part of every process is exposed to many sets of causes of variability at all times, and it would be fantastic to expect all of the rest to behave themselves while a selected one is varied. The experiment was therefore repeated, this time using the randomizing techniques.

The first step was to randomize the mounts to be fed to the sealing machine whose speed was to be varied. The mounts were the product of the last process performed before sealing. The randomizing of mounts, therefore, randomized the effects of every process which preceded sealing, and effects due to sealing would thus be unlikely to be severely confounded with effects due to any process which preceded it.

The random order assigned to the mounts was then maintained through every process subsequent to sealing, including the test itself. Thus all sets of causes, both before and after sealing, affected the lamps in random fashion, and the only causes which could show a real effect in the results would be those due to machine speed itself.

Analysis of the final results showed that machine speed was without measurable effect on life. Further ferreting finally disclosed the real cause in an entirely different part of the process. There is every reason to believe that, if adequate precautions had been taken to neutralize extraneous causes in the original experiment, erroneous evidence of an effect due to machine speed would have been lacking. For in that first experiment the easy assumption had been made that the effects of all other extraneous causes were either non-existent or small enough to be disregarded. But such an assumption was an opinion. After the experiment had been completed, the conclusions drawn had depended on that opinion; the facts had not spoken for themselves.

SPECIAL DESIGNS OF EXPERIMENTS

Much has been written and said about factorial experiments and their value in the study of several sets of causes simultaneously. By means of such balanced designs of experiments it is possible to increase both the breadth of the base of an experiment and its efficiency in preventing duplication of experimental effort. This experimental efficiency is even more spectacular in the designs known as Latin Squares and Graeco-Latin Squares.

Experience indicates, however, that too little emphasis has been placed on the importance of randomizing the effects of extraneous causes which are always present, even in these ingeniously balanced arrangements.

Consider a comprehensive experiment being conducted at the present time to study the effects of various cathode design parameters on the life of fluorescent lamps. The cathode is a tungsten filament of the "coiled coil" type. It is manufactured by winding tungsten wire on molybdenum mandrel wire, then winding this combination again on a steel mandrel pin which is automatically withdrawn when the filament is cut to length. The molybdenum mandrel is then removed by acid treatment. The filaments are manufactured in "schedules" of several hundred or more at a time.

The five parameters whose effects are being studied are:

Tungsten wire diameter.
Molybdenum mandrel diameter (Primary mandrel).
Turns per inch wound on molybdenum mandrel (Primary T.P.I.).
Steel mandrel pin diameter (Secondary mandrel).
Turns per inch wound on steel mandrel pin (Secondary T.P.I.).

By selecting five different values of each of the five different parameters, a 5 x 5 Graeco-Latin Square was laid out to study these five parameters as thoroughly as could be done with a test on only 25 lamps.

After the plan of the experiment had been arranged, an order was transmitted to the Filament Department and attached was a list of the 25 different designs of filaments for the experiment. The list was made out as shown, Table 1, where the five values of tungsten wire diameter are represented by A, B, C, D, E; the five values of primary mandrel diameter by I, II, III, IV, V; the five values of primary T.P.I. by 1, 2, 3, 4, 5; the five values of secondary mandrel diameter by a, b, c, d, e; and the five values of secondary T.P.I. by v, w, x, y, z. The combinations of designs in this list met the requirements for a Graeco-Latin Square, in that each value of each parameter was associated with each value of each of the other parameters once and only once.

Made out in this order, however, the list would have implied that the schedules of experimental filaments should be manufactured in the listed order. If this had been done, there would have been serious faults in the procedure. With respect to wire diameter, there would have been the fallacy of manufacturing all schedules of filaments with wire diameter A, then all with wire diameter B, etc. In this way any possible time-to-time trends due to extraneous causes would have been severely confounded with the effects of wire diameter. With respect to primary mandrel diameter, and to some extent with respect to the remaining three pa-

rameters, there would have been the fallacy of alternating. In this way, any possible cyclical variations, keeping in step (or nearly so) with the alternations, would have caused severe confounding.

The order of the list was therefore permuted, by card drawing, and the revised list as sent to the Filament Department was as shown in Table 2. This included the same designs as the list which had been laid out in order, but the suggested procedure had been completely randomized. In addition to revising the list, specific instructions were issued directing that the schedules of filaments be manufactured in the order shown, and the job was followed closely to make sure that the listed order was followed to the letter at every stage of the filament manufacturing process.

It was fortunate that this was done, for the following of random order often adds to the work involved in carrying out certain parts of a process, and there is a temptation to sort, in order to expedite the job. This case was no exception.

For instance, between primary and secondary coiling, the tungsten-molybdenum combination is annealed in a hydrogen furnace. The specified temperature of the furnace is different for different values of primary mandrel diameter. Furthermore, it takes time to change the furnace temperature. In order to expedite the experimental procedure at this point, the foreman proposed that he use five different furnaces, setting one at the temperature for diameter I, a second at the temperature for diameter II, etc., and then run all diameter I through the first furnace, all diameter II through the second, etc. The engineer, of course, could not allow this procedure. The foreman then asked if, using a single furnace throughout, he could first set at the temperature for diameter I and anneal all five schedules of diameter I, then set at the temperature for diameter II and anneal all five schedules of diameter II, etc. Again the engineer refused, and insisted that the listed order be followed.

This insistence was absolutely necessary. There can be differences, other than temperature, between furnaces and within one furnace from time-to-time. Among the possibilities are atmospheres, temperature gradients, etc. The effects of

TABLE 1

Design No.	Wire Diam.	Primary Mandrel Diam.	Primary T.P.I.	Secondary Mandrel Diam.	T.P.I.
1	A	I	1	a	v
2	A	II	2	e	x
3	A	III	3	d	z
4	A	IV	4	c	w
5	A	V	5	b	y
6	B	I	2	b	w
7	B	II	3	a	y
8	B	III	4	e	v
9	B	IV	5	d	x
10	B	V	1	c	z
11	C	I	3	c	x
12	C	II	4	b	z
13	C	III	5	a	w
14	C	IV	1	e	y
15	C	V	2	d	v
16	D	I	4	d	y
17	D	II	5	c	v
18	D	III	1	b	x
19	D	IV	2	a	z
20	D	V	3	e	w
21	E	I	5	e	z
22	E	II	1	d	w
23	E	III	2	c	y
24	E	IV	3	b	v
25	E	V	4	a	x

TABLE 2

Design No.	Wire Diam.	Primary Mandrel Diam.	Primary T.P.I.	Secondary Mandrel Diam.	Secondary T.P.I.
1	C	II	4	b	z
2	C	III	5	a	w
3	B	III	4	e	v
4	B	V	1	c	z
5	D	IV	2	a	z
6	A	IV	4	c	w
7	E	I	5	e	[illegible]
8	E	V	4	a	x
9	A	III	3	d	z
10	B	IV	5	d	x
11	A	I	1	a	v
12	E	II	1	d	w
13	A	II	2	e	[illegible]
14	D	III	1	b	x
15	B	II	3	a	y
16	A	V	5	b	y
17	D	II	5	c	[illegible]
18	E	IV	3	b	v
19	E	III	2	c	y
20	D	V	3	e	w
21	C	V	2	d	[illegible]
22	B	I	2	b	w
23	C	IV	1	e	y
24	C	I	3	c	x
25	D	I	4	d	[illegible]

such variables belong in the experimental error, and must not become associated with a parameter being investigated. Randomizing keeps them in the experimental error. The procedures proposed by the foreman would have made them become associated with primary mandrel diameter.

The objection might be made here that, since different primary mandrel diameters require different annealing temperatures, this temperature effect is confounded with primary mandrel diameter anyway. Reflection indicates, however, that specified changes in annealing temperature are not extraneous causes, but are *necessarily* associated with changes in mandrel diameter, and decisions between mandrel diameters necessarily carry with them decisions between corresponding annealing temperatures. The purpose of the random procedure is to prevent confounding by neutralizing the effects of *unknown* and *uncontrolled* causes which otherwise might become associated with the parameters during the experiment, but would not necessarily be so associated at other times.

The lamps, now on test, will not reach the ends of their lives until well over a year from now. During the experiment, it would have been easy to assume that these extraneous between-furnace and time-to-time effects were either non-existent or small enough to be disregarded. But such an assumption would have been an opinion. When the data have been assembled, the conclusions then drawn would depend on that opinion; the facts would not have spoken for themselves. Erroneous conclusions, after many months of experiment and test, would be a high price to pay for a few hours saved during experimental filament processing by work simplification which "derandomizes" the procedure.

BALANCING VS. RANDOMIZING

Frequently there is a clear choice between balancing and randomizing a particular source of variability. Consider, for instance, a recent experiment on incandescent lamps.

The objective was to study the effect of varying degrees of filament distortion on the life of lamps, and also how this varied between two different types of mount construction. Two lamps of construction I and two lamps of construction II were selected for each of five different degrees of filament distortion, making 20 lamps in all.

TABLE 3

		Construction I		Construction II		Average
		Rack A	Rack B	Rack A	Rack B	
Degree of Filament Distortion	1	116	115	129	113	118
	2	94	83	106	134	104
	3	81	93	135	98	102
	4	118	109	105	129	115
	5	80	73	102	87	85

Averages					
Rack A	107	Construction I	96	105
Rack B	103	Construction II	114	

TABLE 4

		Construction I		Construction II		Average
		Rack A	Rack B	Rack A	Rack B	
Degree of Filament Distortion	1	124	107	137	105	118
	2	102	75	114	126	104
	3	89	85	143	90	102
	4	126	101	113	121	115
	5	88	65	110	79	85

Averages					
Rack A	115	Construction I	96	105
Rack B	95	Construction II	114	

At the life test laboratory there were two test racks, each having 10 sockets. Any difference which might exist between racks was therefore a source of variability. Such a source of variability would be badly confounded with type of lamp construction if all 10 lamps of construction I were tested on rack A and all 10 lamps of construction II were tested on rack B. It would be better to neutralize this possible effect by assigning lamps to racks at random. Would it be better still to balance this possible effect by assigning one lamp of each construction-distortion to each rack?

In the actual test, the latter course was chosen; i.e., the possible effect of the racks was balanced. The final life data (expressed as a percentage of rated life) were as shown in Table 3. Analysis of these data indicated that the difference between constructions is highly significant, the differences due to distortion are significant, but that there was no measurable difference between the racks.

If, however, there had been a real difference between the racks, the data might well have appeared as in Table 4. Analysis in this case would indicate a real difference between racks, and would also indicate, as before, a high significance in the difference between constructions, and significant differences due to distortion. Thus, even with a real difference between racks, the value of the balanced experiment would be practically unimpaired.

Suppose, on the other hand, that with this real difference between racks existing, the test had been randomized instead of balanced. If this had been done, each lamp could have been placed on either rack, and the life data might well have appeared as in Table 5. Analysis in this case would indicate that the dif-

TABLE 5

Degree of Filament Distortion	Constr. I	Constr. II	Average
1	127 104	105 117	113
2	102 95	126 114	109
3	89 105	123 90	102
4	101 126	121 93	110
5	88 65	110 99	90
Ave.	100	110	105

ference between constructions *and* the differences due to distortion, both shown to be significant in the balanced experiment, would appear to be within reasonable limits of chance and therefore not considered significant at all.

The reason for this is the loss of sensitivity due to randomizing the racks. By randomizing racks, an appreciable source of variability would have been thrown into the experimental error, and this larger experimental error would have made the real effects obscure. In the experiment in which the effect of the racks was balanced, the difference between racks was stripped out of the experimental error, and this made the experiment more sensitive.

It is apparent that nothing is lost in any case by balancing, whether the potential cause has a real effect or not, but that sensitivity can be lost if a real cause is randomized. When a clear choice is available, it is better to balance a potential cause which could have been randomized than to randomize a real cause which should have been balanced.

THE PROBLEMS OF APPLICATION

The applications of these techniques of balancing and randomizing present to the quality control engineer a most interesting and challenging opportunity. While the principles are universal, each actual case has its own peculiar physical problems which tax the ingenuity. The greatest of the problems, however, are the human ones. The perversity of inanimate objects can be neutralized, but the fallibility of human beings will present difficulties for many years. One of these is the tendency persons have toward order. This is natural, for most tasks are best accomplished when carried out in an orderly manner. In investigations of the nature we have been discussing, however, order can be carried too far. This will be so when operators and testers "derandomize" the procedures by sorting. It has been found necessary to take special precautions to prevent this. Careful instructions and close follow-up are essential.

A more difficult problem in the human relations involved is the convincing of various persons that careful randomizing is actually a necessary prerequisite to valid conclusions. Generally the more familiar a person is with a process, the more difficult it is to convince him of the necessity of randomizing at certain stages of his particular process. His tendency is to assume that there are stages at which randomizing is unnecessary. If a specific potential extraneous cause is suggested to illustrate the need of randomizing, he either suggests a specific remedy in the procedure for *that* cause, or dismisses the cause as unimportant. As other potential causes are suggested, he continues to suggest specific remedies or to dismiss the causes as unimportant.

Suggesting specific remedies for specific causes amounts to the classical "control of conditions." The specific remedies often add substantially to the technical problems and cost of the experiment, and they can never give full confidence in the validity of conclusions, for it is never possible to name *all* the possible extraneous causes. Randomizing, on the other hand, even if it seems to be "fussy," is usually basically simple, and does yield full confidence, for it automatically neutralizes *all* extraneous causes.

Dismissing a suggested cause, or other causes, as unimportant amounts to injecting an opinion into the experiment before it is performed. The fundamental purpose of an experiment is not to confirm opinions, but to make the facts speak for themselves in the language of data. If it is worth while to invest time and money in experiments, it is certainly worth while to make the data tell the truth.

Quality Control
A Tool for Human Engineering*

ROSCOE SMITH

Director of Quality Control, Ford Motor Company

IT will be my purpose to discuss here my Company's experience with a management tool which we think offers great promise to business and industry generally. I shall talk about Quality Control and its relation to Human Engineering as we have experienced it at Ford Motor Company.

A word of caution first. We hear a lot about controls these days—housing controls, wage and price controls, and material controls—and I would like to ask you not to place Quality Control in this category.

Quality Control is not, as some people think, a control system whereby we are satisfied with what is good enough. We have no intention of holding quality down to some pre-determined level. Our aim is constantly to improve the quality of our products—to refine, to the greatest practical degree, the precision of our production.

Some of you know what we are doing and what we have done in this field at Ford's. Yet the more we work with Quality Control the more we realize what a vast and far-reaching field it is, and how much there is to accomplish. As we learn, we are more than glad to pass our knowledge on to others.

* An address given to the Society for Advancement of Management in New York, on November 3, 1950.

By the same token, we constantly gain from the ideas and experiences of others. It's the old story of the difference between ideas and dollars. If you and I swap dollars, we each still have a dollar. But if you and I swap ideas we each have two ideas.

The specific idea that I want to discuss in connection with our Quality Control program concerns the effect that good Quality Control has on people. This particular development of our Quality Control program is something of a by-product of our basic program.

BY-PRODUCTS OF QUALITY CONTROL

Practically every industry has its by-products. For example, years ago, when you butchered a steer, you butchered it for the meat and the hide. You never gave a thought to the possible commercial value of the waste products. They were just something you had to get rid of. But go through a modern meat packing plant today and see what happens to all the "spare parts" of a slaughtered animal! Every one of them is used, and they form an important part of the profit picture of that industry and make a distinct contribution to the country's economy.

When we brought this Quality Control "animal" into the Ford Motor Company and made it a basic manufacturing policy, we expected to get a certain amount of meat and a certain amount of hide. First and foremost, we felt that through the effective use of control charts at every practical step of manufacturing, we would be able to maintain a high quality level and build an increasingly better product.

Results indicate that we were not wrong. We feel that we have made a good start and we are continuing to expand our quality program. But Quality Control is also paying off in such unforeseen by-products as improved worker morale and pride of accomplishment. In fact, it turns out to be one of the most powerful tools for Human Engineering that I have come across in many years of experience in the industrial field. By the use of Chart Control our people know where they stand in relation to the job they are doing. Uncertainty and misunderstanding, as well as scrap, have been eliminated. Pride and a feeling of security have taken their place. Our workers have a score card on their performance. Their job becomes a challenge instead of a chore.

Ford, as a Company, keeps a score card on its activities. We establish our goals and work toward them. We check our progress and we measure our performance. But it is not enough for top management alone to have targets. We must have individual targets—targets for Joe Doakes and Bill Brown—and all the other men who make our automotive parts. We must inject a personal challenge—an incentive for job improvement.

Those of you who play golf know what I am talking about. Even if you can't get a hole-in-one you keep on trying. You try to improve your score. In fact, that's one of the reasons you enjoy golf. But if nobody kept score and you just clubbed the ball around you wouldn't be very interested in your performance.

That's the way it was with a man working before Chart Control was introduced. He went along for days and weeks, maybe months, turning out the same identical part. His work was inspected. Some of his output was accepted and some was rejected. He didn't know whether the rejections were his fault, or the fault of the machine or the material. He didn't know how his output compared in quality to that of the man across the aisle. In other words, he didn't know the score. And since he didn't know the score, how could he possibly have any real interest in his performance?

But put a score card on that man's activity and watch the difference!!

The score card is the control chart. It might be compared to a highway with shoulders and a ditch on either side. If your car gets on the shoulder it's a caution. If you hit the ditch, it's too late. The safety limits of the control chart are represented in the same way, by a top line and a bottom line with a clear road in between them. They are called the upper and lower control limits. Group samples are then taken directly from production at regular intervals and their average dimension plotted on the chart. Providing the plotted points fall between the two limits the parts are according to specification. If they indicate a tendency to drift towards the control limits it means the job is going out of control. Forewarned by this tendency we can take corrective action before any damage is done.

The man on the machine may have little idea of the statistics involved in making his chart a reliable score card but he soon learns the basic story it tells. He knows where he stands on quality. He is an individualist. When his chart shows the quality of his job is going out of control, he knows it's time to do something about it, and he feels it's up to him to improve it. He gets a kick out of tackling his own problems and suggesting from his own experience what can be done to make the job better. Instead of just working eight hours a day at a monotonous task, he is striving eight hours a day for self improvement. His morale rises with the challenge and he has reason for his enthusiasm.

A QUALITY PROMOTIONAL PROGRAM

To stir this enthusiam to even greater heights we have developed what we call a Quality Promotional Program. This program is designed to let the worker know how we feel about quality and what our intentions are. It is, of necessity, a mass psychological program. Our most recent stimulant was a Quality Queen Contest for our 125,000 hourly workers. In talking to one of the boys after the Queen had been elected, he said it was just another matter of applied statistics. The employees had selected the girl whose "normal distribution" they most appreciated. Believe me, he was right!

In addition to this contest we use posters, pay envelope stuffers, exhibits, slogan contests, suggestion awards and newspaper articles. We even established our own Quality Control News, a monthly magazine circulated to all foremen and supervisors of the Company. We developed training courses, for management, for inspection people, and for production people. We circulated pamphlets with simple, easy-to-understand explanations of Chart Control at work. In the near future we expect to produce a film on Quality Control. In reality there is no end to the things that can be done to stimulate quality thinking.

QUALITY CONTROL STIMULATES PRIDE OF PERFORMANCE

Quality thinking puts a man in the right frame of mind for Quality production. Chart Control gives him a quality score on his activity.

It also gives him a feeling of team security. It puts him on a man-to-man basis with his boss. Chart Control shows that poor quality is not

always due to inferior workmanship. Sometimes the tools are at fault, or the machine is out of adjustment, or the stock is wrong, or the wrong technique is being applied. In short, Management may be at fault for not providing the best and most efficient equipment for the job. When chart control brings conditions like these to light, and Management promptly corrects them, the worker feels a confidence in his superiors. He is inspired to do his share—to do the kind of work he and his employer will be proud of.

Let me give you an example of what can happen when we use a little ingenuity in stimulating this pride of performance in our workers. We had a problem in one of our departments. We weren't getting the quality we wanted without a lot of expensive rework. The solution came from the superintendent of Quality Control in that building. He devised an interesting method which gave production men and everybody concerned the quality score every half hour. He had a big board installed, five times as large as the ordinary control chart. The board had spaces for the various types of defects. Each space was divided to show the average number of defects per unit, and the percentage defective. Then he added traffic signals, in the form of green, yellow and red discs.

When the quality of the part was within specified limits, the inspector put up a green disc. A yellow disc meant, "You're running into trouble." And a red disc meant that production had to stop until the trouble was corrected. In other words, the process had gone over the shoulder and into the ditch.

The superintendent's whole idea was to isolate the causes of poor production and point them out to his workers—to cooperate with them and help them. The response from his men was terrific. A red disc to them was the same as a red flag to a bull. They didn't like the looks of it. It was a reflection on their intelligence and their workmanship. Their greatest satisfaction came from keeping that red disc off the board. The effect on morale was almost magical. Although production schedules have been increased about 70%, the quality is better than it ever was before.

Actually, all we did was put a bigger challenge in the chart. We didn't change the information—we simply dramatized it.

BETTER TEAMWORK BETWEEN PRODUCTION AND INSPECTION

The more I think about Quality Control as a tool for Human Engineering the more ideas I get about it. One of the finest assets a company can have is an all round healthy spirit of cooperation. That makes me think about the feuds we used to have between inspection and production people. These functions were often in opposition. And for this reason. On one hand there was a production schedule to be met and on the other a quality level to be maintained. Generally speaking, there was a time lag between detection of poor workmanship at inspection and its correction at the point of manufacture. As a result, production schedules might suffer—quality go down—and blood pressures up.

But all this has changed. Chart Control brings the inspection function right to the production machine. Hour by hour the production men know the quality of their products. Scrap and rework are reduced. Schedules are easier to maintain. Production and inspection work together as a team.

Let me give you an illustration. On one particular job on which we were using one hundred percent inspection our defectives ran as high as 12%. The use of Chart Control on this job cut defects to 1.4%. Several weeks later while talking with the foreman we jokingly suggested taking Chart Control off the job. The production foreman turned purple and then exploded. "Like Hell," he said, "Those charts stay on the job. My people are pulling together like they never pulled before, and we are all reaping the benefits."

There is the same resounding echo in all of our production departments. They know the value of Chart Control and we couldn't take it away from them if we wanted to.

QUALITY CONTROL IMPROVES RELATIONS WITH VENDORS

Still another by-product of our Quality Control program is the far-reaching and beneficial effect it has on our vendors. Here, it is a powerful tool in the promotion of mutual understanding, and the merging of aims and purposes.

At Ford, we never forget for a moment that we depend greatly on outside suppliers in this business of building automotive products. There are thousands of vendors who supply us with parts and materials. No company, however big, could manufacture economically each and every part that goes into a finished product as complex as a car, a truck or a tractor. Nor should it expect to. Over the years, the building of many of the vital parts of the automobile has become the job of specialists. Spark plugs, carburetors, batteries, tires—these are only a few of the hundreds of important items we buy from firms who may devote their entire resources to building one specific product. They know from long years of experience the problems and obstacles peculiar to their industry. They have met these obstacles and have overcome them. Whenever we issue a purchase order we accept—and respect—this substantial backlog of experience.

Just as our suppliers bring to us the fruits of their experience, so also do we attempt to give them the benefit of ours. Statistical Quality Control, for example, was new to most of our suppliers when we first established it as a manufacturing policy. As we learned more about it, we passed our knowledge on to them. Last spring, the demand for information was so great that we held a special training course in Statistical Quality Control for our vendor representatives. Since then, to satisfy the increasing interest of our vendors, we have repeated these training courses. They have been attended by hundreds of people from all fields of industry. Requests for our training material—from universities, students, and industry in general have surpassed all expectations.

We have had some mighty fine letters from the vendors who have participated in our program. This is what we received from the president of a gear company. "Although we have had a quality program in our plant for several years we feel that the help your people gave us has opened the way to new accomplishments by statistical quality control methods. We look forward to working even more closely with you in this field."

An officer of an electric company wrote: "We are grateful for the opportunity to have participated in your quality control program. The educational material you sent has been extremely helpful. Both ven-

dors and buyers will benefit greatly when more companies commence to work together on quality control."

Letters like these certainly indicate that better relationships with our suppliers are not the least important of the by-products of our Quality Control program. The willingness and the opportunity of buyers and vendors to pool their knowledge in a sincere effort to improve quality must go down as a milestone in Human Engineering.

Of course, these suppliers of ours got along for a good many years, just as Ford did, before Chart Control was ever heard of. And through the years they have done a commendable job in supplying us with parts that we—and our customers—could depend on for many thousands of miles of trouble-free motoring.

But, of necessity, our suppliers were obliged to give careful inspection to every shipment; and we, too, had to inspect every shipment on arrival. This was double inspection but it was the only way we could safeguard quality. Even then we could not enjoy the degree of reliability we desired.

QUALITY LEVEL CERTIFICATION

So another by-product of our Quality Control program was born. We call it Quality Level Certification. This means that we and our vendors sit down at the same table and dovetail our respective quality programs for the good of both. It entails the use of sound, reliable sampling plans which insure that we and our vendors are talking the same language. It has many important advantages. It eliminates friction and promotes good faith and understanding. Certification recognizes a practical quality level—one acceptable to the Ford Motor Company and one attainable by the vendor. It ensures that inspection methods are correlated and that rejection and acceptance is based upon common measurements and standards. It involves a willingness on the part of the Ford Motor Company and vendors to discuss freely any problems that arise. Specifically, it generates cooperation and goodwill.

MEN AND MACHINES

A never-ending search for better and sharper tools to do the jobs required of them has been a constant concern of American management. It was this concern which produced standardization of parts, line assembly, and the use of large, high-cost machines. It was this concern which produced quality control—called by some, one of the sharpest management tools developed in the last half century.

Important as quality control is to industrial production, I cannot help feeling that our experience has shown it to be a equal importance in meeting our problems of human relations.

Machines alone do not give us a high level of production. It is achieved by both machines and men. We have come a long way toward perfecting our mechanical operations, but we have just begun to take the human factor into consideration.

I am convinced that quality control, with its emphasis upon the man at the machine, can be one of our most valuable tools for achieving better human relations in business and industry.

Application of Statistical Techniques to the Physical Testing of Plastics*

C. H. ADAMS

Research Department, Monsanto Chemical Co., Plastics Division, Springfield, Massachusetts

Although plastics are relatively new engineering materials, they are finding many and diversified applications because of their unique physical properties. In the past, the cut and try technique has often been used in determining whether or not a given plastic material will be suitable for a particular application. However, management is becoming increasingly aware that this is a costly way of doing business and that the choice of material can and should be based on adequate physical properties data. These data should reflect, insofar as possible, the magnitude of the property changes due to the variables encountered in the processing, fabricating, and normal useful life of a plastic article. Such information could formerly be realized only upon the completion of a tremendous testing program. Fortunately, the mathematical statistical techniques now finding widespread application in industry (1)** provide a means for studying more efficiently the physical properties of plastic materials.

Relegated to the realm of history in the short span of less than a year in our laboratory was the system of conducting a series of tests and interpreting the data with the aid of only the mean and mean deviation test statistics. Experimental or factorial design now precedes all experimental work involving evaluation of the physical properties of plastic materials.

PREVIOUS WORK

The science of mathematical statistics is by no means a new one. Mathematicians have been dealing with probability for many years. Without a doubt, the first application of mathematical statistics to problems of a practical nature occurred in the days of Laplace who was requested by gambling interests to devise a system for detecting cheating at the gaming tables. Large scale use of statistical techniques

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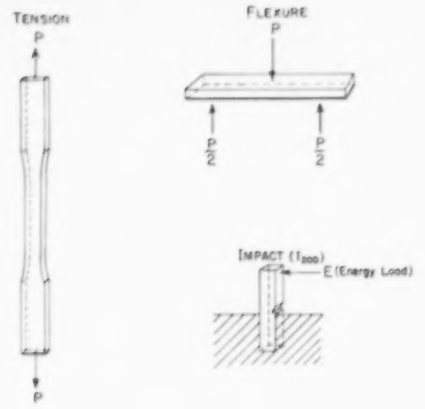
**Numbers in parentheses refer to bibliography, appended.



Schematic Representation of Tension, Flexure, and Impact Tests

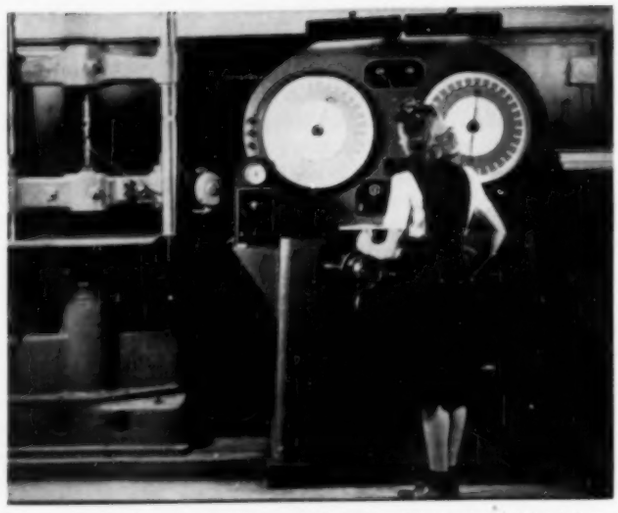


Figure 1—**Tension Test on Universal Testing Machine**

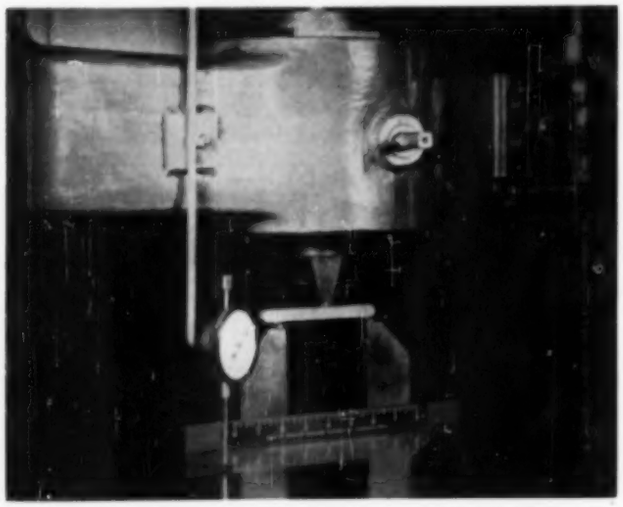


Figure 2—**Flexure Test on Universal Testing Machine**

Figure 3—**Izod Impact Tester**

was first made by research workers in agronomy. From this field, its application spread to bacteriology, biochemistry, and nutrition. To R. A. Fisher (2) can be given credit for much of the work associated with the development of the analysis of variance. It is this particular tool of statistics that is becoming of such importance in industry today. His work was preceded by that of Student (3) whose t distribution is familiar to everyone who at one time or another has been concerned with the confidence limits of a given mean and/or the comparison of two means.

The application of mathematical statistics to quality control (4) during World War II served to stimulate interest in the widespread use of statistical techniques on a much broader scale than ever before. Today, considerable progress toward the goal set forth by W. A. Shewhart and W. E. Deming (5) has been made, namely: "The long range contribution of statistics depends not so much upon getting a lot of highly trained statisticians into industry as it does in creating a statistically minded generation of physicists, chemists, engineers and others who will in any way have a hand in developing and directing the production processes of tomorrow."

PHYSICAL TESTS ON PLASTICS

The physical tests conducted on plastic materials are many in number (6). This discussion will be limited to a few of the more common mechanical ones. Electrical tests have been omitted only because the experiments shortly to be described deal solely with mechanical testing.

The most common mechanical tests (performed in our laboratory) are tension, flexure, and impact. The tension and flexure tests are carried out on a machine capable of applying deformation to a specimen under controlled conditions and indicating with a known degree of accuracy and precision the force applied. Tension, as the name implies, refers to applying the force along the longitudinal axis of the specimen. Figure 1 shows a tensile test in progress on the Universal Testing Machine. The specimen is pulled between the two crossheads to the left of the load indicating dials.

Flexure is simply a bending operation in which the material is usually loaded as a simple beam, i.e., supported at the ends with load applied at the center. Figure 2 is a closeup at the force applying system of the

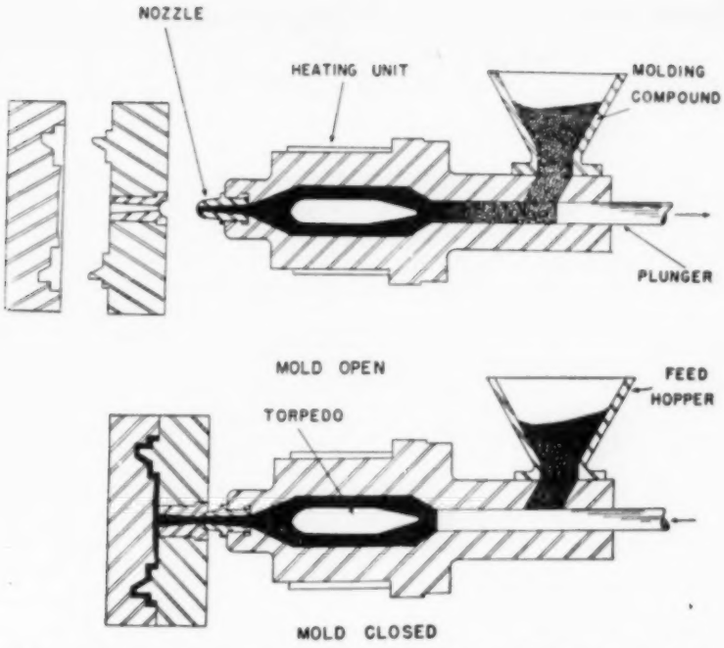


Figure 4—**Cross-section of Typical Injection Molding Machine**

Universal Testing Machine with a flexural test underway. Both tension and flexure testing is done at comparatively slow rates of loading.

Impact testing differs from the preceding in the time scale of load application. The present impact test employed by the plastics industry, namely, Izod, applies an energy load to the test specimen in the form of a cantilever beam. This load is applied by a carefully calibrated pendulum, see Figure 3. The amount of kinetic energy removed from the pendulum system due to breaking the specimen is indicated on a dial.

VARIABLES AFFECTING PHYSICAL PROPERTIES OF PLASTICS

The mechanical properties of plastics are a function of many variables. The first of these to be considered is base resin type. Synthetic resins (7) from which plastics are manufactured may be classified under two general headings, thermoplastic and thermosetting. Materials which can be made to soften and flow repeatedly with the application of heat and pressure are classified as thermoplastic. Those materials which become hard and infusible upon application of heat and pressure are referred to as thermosetting. The mechanical properties of these two types are significantly different; thermoplastic compounds usually exhibit higher ductility and greater softness. Within each of these groups are many different chemical types and each chemical type can be further modified by formulation changes. Other important sources of variability are those due to processing and fabrication. In these operations, temperature, pressure, time, and machine design combine to control the properties of the finished plastic item.

The final variability source is that of testing in the case of specimens and field use in the case of consumer items. The known variables of testing can be rather closely controlled, i.e., temperature, humidity, specimen size, straining rate, and precision of testing machine. However, the conditions under which a consumer item is used are obviously impossible to control within specified limits. Moreover, it is recognized that a popular misconception exists in the minds of many users to the effect that plastics are indestructible materials which will stand unlimited abuse and rough treatment. Thus, it is important that the manufacturer of plastic materials educate the consumer regarding not only the superior characteristics of his materials but also their limitations. In order to do this intelligently, he must have a thorough understanding of the effect of variables encountered in the service life of his product upon its physical properties. This can best be attained through systematic study in the laboratory.

EXPERIMENT TO STUDY EFFECT OF FABRICATION VARIABLES ON THE PHYSICAL PROPERTIES OF STYRENE PLASTIC

A series of experiments have recently been completed in which the effect of certain variables in the injection molding process upon the mechanical properties of styrene plastic was determined. The cross section of a typical injection molding machine is shown in Figure 4 (8). The plastic material enters the machine through the feed hopper as solid granules or pellets. It is carried through the cylinder by the plunger into the heated or plasticizing (softening) region and finally into the cold mold (die) where it solidifies and is removed as the finished object. Inasmuch as the process is one of flow it was surmised that heater temperature could be related directly to physical properties, for these are a function of how rapidly and at what plasticity material is forced into the mold (die).

The first experiment was therefore designed to show the effect of heater temperature upon the tensile, flexural, and impact properties of a commercial grade of styrene plastic. The specimens were injection molded in a Reed-Prentice 8 oz. machine. The machine was fitted with a six cavity die which at one shot produced six different types of standard A.S.T.M. specimens. The heater temperature was varied from 375-575°F. while molding pressure, die temperature, and cycle were held constant within control limits.

The strength tests were carried out according to A.S.T.M. procedure in the standard laboratory atmosphere of 77°C. and 50% R.H. (1948). The data showed a decrease in strength with increasing heater temperature. The significant thing to note, however, is that the relationship between the measured mechanical properties and heater temperature is non-linear (Figure 5). This indicated interaction and demonstrated the inadequacy of the experiment.

Accordingly, it was felt advisable to carry out another experiment based on a factorial design in which the effect of variables in addition to

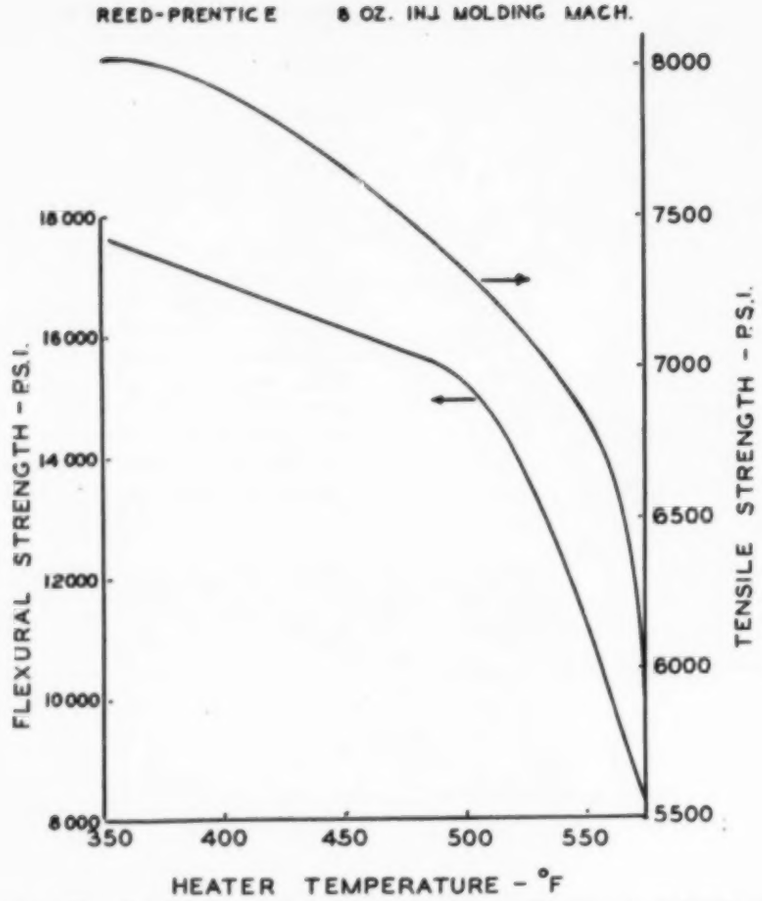


Figure 5—**Tensile and Flexure Strength vs. Heater Temperature for Styrene Plastic**

that of heater temperature could be studied. The second experiment (Figure 6) was therefore designed to include three of the most important controllable variables in the injection molding process: heater temperature, die temperature, and molding pressure. Heater temperature was allowed to operate at four levels while molding pressure and die temperature were varied through three levels. The resulting factorial design was a 36-column by 1-row experiment. Replications in each cell were five.

The molding was done on a laboratory size 1 oz. Watson-Stillman injection machine. The specimen molded was a 2½ x ½ x ⅛" bar and was tested in flexure. The reason underlying this choice of specimen was that past experience indicated that this type of bar, when tested in bending, showed the effects of molding to a greater extent than did other types.

The flexural strength data showed that molding pressure in the range studied, i.e., 800-1000 psi, had little effect on strength. It further showed a strong interaction between heater temperature and die temperature (Figure 7). Whether this is the same interaction encountered in the previous experiment has not been determined. It is important to note that had this been a single variable experiment operating at a fixed heater temperature of 425°F., one would have perhaps drawn the general conclusion that raising the die temperature improved the flexural strength. Similar erroneous conclusions would have been possible based on variations in heater temperature only. The correct conclusions to be drawn from this experiment are that the effect of heater temperature variation is minimized at the low end of the die temperature scale and that the effect of die temperature variation is minimized at the high end of the heater temperature scale.

The practical application of this type of information is of great importance to the molder. From such data, he can predict the most favorable operating conditions for his equipment.

EXPERIMENT TO STUDY VARIABLES ASSOCIATED WITH TESTING

One of the most important mechanical properties of plastic mate-

Mold Pressure psi	800				900				1000			
Heater Temp. °F. (set)	400	425	450	475	400	425	450	475	400	425	450	475
Die Temp. °F. (actual)	85 115 140	85 115 140	85 115 140	85 115 140	85 115 140	85 115 140	85 115 140	85 115 140	85 115 140	85 115 140	85 115 140	85 115 140
Mold. Order and Condition No. Not Randomized	28 36 46	21 29 44	34 32 45	55 47 50	28 37 47	32 40 50	35 43 53	56 52 60	30 38 48	33 41 51	39 54 54	57 53 60
Flexural Strength (No. observations)	555	555	555	555	555	555	555	555	555	555	555	555

Figure 6—**Factorial Design of Molding Experiment. Watson-Stillman 1-oz. Injection Molding Machine. 2½x½x⅛" Mold**

rials is that of toughness. It is furthermore, one of the most elusive to measure. The most widely accepted test, currently in use, to measure this property is the Izod impact (6).

Plastics are often purchased against a minimum Izod impact strength specification. Consequently, it is important to know the variability and the sources thereof common to the Izod method. Some time ago, an experiment was conducted in which the data obtained by two laboratories on a given styrene plastic were compared. It was apparent that the difference observed was due to one or more differences in technique between the laboratories. Accordingly, the data were sent to our statistical group for evaluation. This group reported very shortly that nothing in addition to that already known, which was very little, could be learned from these data. The reason for this state of affairs was readily apparent: the experiment had not been properly designed (Figure 8). It so happened in this particular instance that the experiments were neither time consuming nor costly. Consequently, a valuable lesson had been learned with a minimum of serious consequences. The lesson, of course, is this: design the experiment systematically in accordance with recommended statistical practice. If there is any doubt as to how this should be done, consult the statistician before conducting the experiment. A little extra time spent on the design will be more than compensated for by the time and money saved later on.

Naturally, the next step in isolating the sources of variability in the Izod test was to design another experiment, the data from which could be subjected to a straightforward statistical analysis. The possible sources of variability included in this design were: (1) laboratories; (2) testing machines; (3) notching; (4) ends of bars; (5) material. The same laboratories participated in this experiment (Figure 9), which was set up as a factorial design of 4 rows by 6 columns. Replications in each cell numbered 5. A known source of variability, that of the force with which the specimen is held in the machine, was not studied in this experiment. It was held at a nominally fixed value within each laboratory. Thus, the effect due to this cause was included with that due to differences in testing machines.

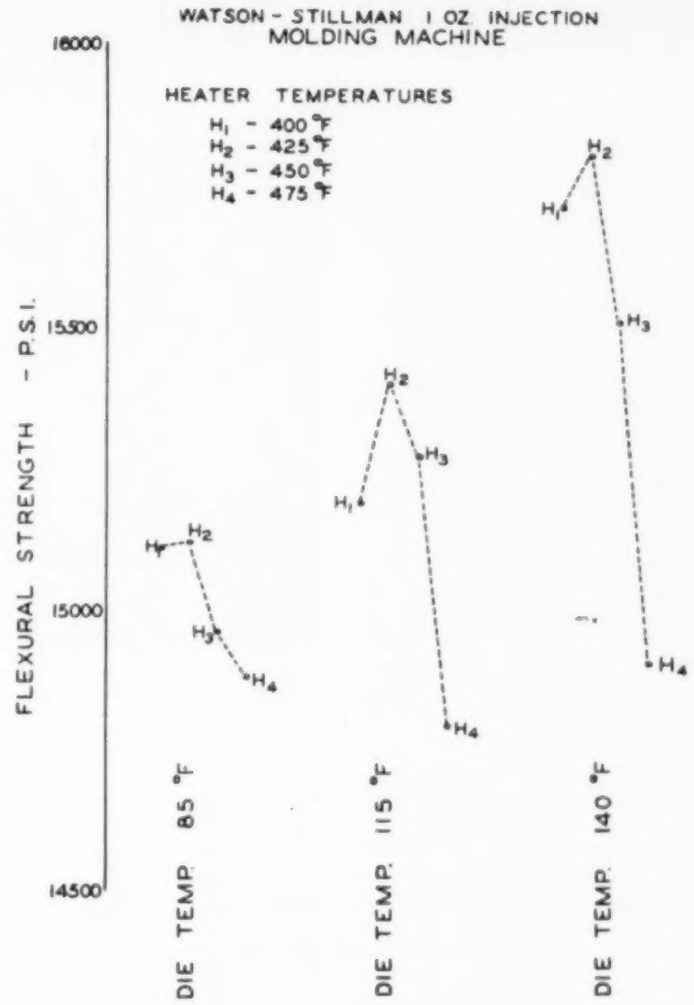


Figure 7—**Flexure Strength vs. Molding Conditions (Factorial Experiment) for Styrene Plastic**

An analysis of variance applied to the test data indicated significant differences to exist due to testing machines and notching of the test specimens. There was a big notching by material interaction. Thus, notching of the A specimens was better than for the B specimens. In the data from one laboratory alone, notching only was significant. The data further indicated the presence of systematic errors in addition to the replication error which was probably due to a non-randomization of tests. The replication error for one laboratory was appreciably lower than for the other. A further conclusion drawn from these data was that: (1) other sources of variability must be considered or (2) the known sources of variability must be controlled within more precise limits.

	Test Monsanto		Test NBS	
Material	P1	P1A1	P1	P1A1
Notch Monsanto	0.276 (10)	0.334 (10)	0.230 (10)	.....
Notch NBS	.....	.....	.....	0.277 (10)

Figure 8—**Experimental Layout Lacking Factorial Design**

EXPERIMENTAL DESIGN, BASIC CONCEPTS

As pointed out earlier in this paper, an analysis of variance can only be carried out on data obtained from an experiment of suitable design. Brownlee (1) points out that a situation suitable for the analysis of variance may arise in several ways:

1. By accident, the process may have a suitable structure as it stands.
2. By slight modification of existing manufacturing (or testing) procedure.
3. By deliberate experiment. Thus, several factors may be varied at levels appropriate to a factorial design.

The experiments described indicate that the accidental approach is usually not feasible in the plastics physical testing field. The deliberate or factorially designed experiment should be used almost exclusively in the study of the physical properties of plastics.

The design of experiments is a topic which can be discussed in its entirety only by a competent mathematical statistician. However, there are a few simple rules which can readily be followed by those of us who make use of these techniques in our daily endeavors:

1. Each variable should be included in the design at its maximum and minimum levels. An alternative is to let it vary at three levels.
2. Where experimentation is costly and a factorial design is not economically justified, list variables in order of importance and weigh their contribution to the overall effect through a series of Latin square experiments.
3. Use a minimum of two replications in each cell.
4. Confound cells which are of minor interest.

SUMMARY AND CONCLUSIONS

Statistical design increases the sensitivity of the experiment as well as its validity. Sensitivity is in turn related to economy of experiment. Increased sensitivity and validity may be considered together as increased efficiency and this, of course, is viewed with favor by management.

The experiments described, the first in the processing of plastic materials and the second in the testing of these materials, have shown that a lack of experimental design often results in inconclusive evidence regarding the sources of variance, while data from planned experimentation provide a reliable index to the factors responsible for variance and to the magnitude of the variability due to each of the factors.

		TEST NBS—1 (5A)		TEST NBS—2 (76)		TEST MONSANTO	
		End A	End B	End A	End B	End A	End B
STYRENE RT	Notch NBS	X	X	X	X	X	X
		X	X	X	X	X	X
		X	X	X	X	X	X
		X	X	X	X	X	X
		X	X	X	X	X	X
	Notch Monsanto	X	X	X	X	X	X
		X	X	X	X	X	X
		X	X	X	X	X	X
		X	X	X	X	X	X
		X	X	X	X	X	X
STYRENE C	Notch NBS	X	X	X	X	X	X
		X	X	X	X	X	X
		X	X	X	X	X	X
		X	X	X	X	X	X
		X	X	X	X	X	X
	Notch Monsanto	X	X	X	X	X	X
		X	X	X	X	X	X
		X	X	X	X	X	X
		X	X	X	X	X	X
		X	X	X	X	X	X

Figure 9—**Experimental Design Round Robin Izod Impact Tests of Two Different Styrene Plastics**

Valid test data over a wide range of conditions become more valuable as the ranges and variables are increased in number. The tools of mathematical statistics, i.e. experimental design and analysis of variance, are most important in the satisfactory consummation of this work.

The right plastic for the job becomes more readily determined as physical properties data increase both in quantity and quality. The correct decision early in the development of a new application benefits both the fabricator and plastic materials producer.

One of the prominent testing machine manufacturers uses the following statement in its advertising: "One test is worth a thousand expert opinions." We, interested in plastics physical testing, like to apply a new twist and come out with "One 'factorially' designed physical testing experiment is better than a thousand poorly planned ones."

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Some Legal Aspects of Sampling*

FRANK R. KENNEDY

College of Law, State University of Iowa

WE lawyers envy mathematicians and engineers, who can do such wonders with charts and tables. "They do things better with logarithms." That is the way the late Mr. Justice Cardozo put it in the first sentence of his little book, "The Paradoxes of Legal Science."[1] That is the wail that escaped him when, after putting forth the best in him on a judicial opinion, doubts assailed him as to its wisdom. Engineers, designers of mighty bridges, he thought, were not harrowed by misgivings whether the towers and piers and cables would stand the strain. Thus he wrote, before the collapse in 1940 of the six and one-half million dollar Puget Sound bridge at Tacoma. Bridge builders, of course, do not know all there is to know about building bridges; but compared to the state of knowledge of lawyers, legislators, and judges as to the wisdom of the laws they write and interpret, the engineers' knowledge is as "a rock of solid certainty."

Because scientific methods have wrought such modern wonders as quality control, certain students of our legal system have been sounding a call to lawyers to wake up to the possibilities of scientific investigation of legal problems.[2] One has within the last year advocated the displacement of jurisprudence by jurimetrics, which would take its place beside biometrics and econometrics.[3] Legislators would then presumably be more interested in studying design of experiments and relevant statistical data than in representations of lobbyists and political advisers.

After reading laments over our unscientific approach to lawmaking and law interpreting, it is comforting to come across J. M. Juran's *Management of Inspection and Quality Control*,[4] where he draws analogies—useful ones, I hope—between the Anglo-American system of law and a modern factory system.[5] Quality specifications, he suggests, are laws enforced in the industrial community. These laws may include the unwritten standards of good workmanship enforced by the inspectors and the legislative determinations of the engineers in the form of quality specifications. Inspectors function not only as law enforcement officers; they exercise judicial functions in passing on production's compliance with specifications.

Quality control is of course a quite recent phenomenon, and although its legal implications are important indeed, the law in its development has not yet taken account of them. So far as I have been able to discover, the expression "quality control" does not appear in any recorded opinion or legislation. But of course when a legal question involving quality control is presented to the courts, it will have to be decided. The courts will refer, with the aid of counsel, to rules, principles, concepts, and standards recognized and applied in like or analogous cases. The common law has grown by virtue of this process of applying propositions of law established by judicial precedent and legislation to new problems as they arise, case by case. While, in view of the necessarily tentative, not to say precarious, character of any observations that might be made about the law of quality control, it would be presumptuous for me to undertake a discussion of that subject, I think it may be appropriate here to note "Some Legal Aspects of Sampling." For the courts have considered the validity of sampling to determine the characteristics of various kinds of universes. The sampling problems presented herein are themselves quite elementary, but the principles established by the cases in which they are presented may be applied irrespective of the complexity of the problem.

SAMPLING PRODUCTS PURCHASED BY SPECIFICATION

So far as the law is concerned, a manufacturer of most items is free, theoretically at least, to adopt any system of inspection or quality control—or no control at all. He may, however, bind himself by contract with a particular buyer to adopt and maintain statistical quality control or some other mode of inspection in filling a particular order. I have been unable to verify the extent to which purchase contracts have insisted on the establishment and maintenance of such control by their suppliers.[6] There would seem to be advantages, however, in such a provision in a purchase contract. I am satisfied that statistical quality control has resulted in the setting of much more precise quality specifications in industry generally, which specifications are incorporated in purchase contracts.[7] The insistence of quality-minded purchasers on attainment of specified quality levels is undoubtedly one of the favorable influences operating today to augment the number of producers utilizing quality control techniques. As Archie R. Jackson, Director of Quality Control at Allen B. Wrisley Co., has suggested,[8] it is desirable for both the buyer and the seller to know and to agree as to the size of the sample each should take so that the average of each of their samples will be within a certain interval of the true average of the shipment a certain portion of the time. Such agreements between buyer and seller not only facilitate harmonious dealings, but also permit the effecting of economies in inspection.

Wade Weaver, Director of Quality Control for Republic Steel, reports that it is common practice in the steel industry for the producer to execute a form setting forth chemical and physical analyses as determined by laboratory tests.[9] The form is notarized and is furnished the pur-

*Presented at the Fourth Midwest Quality Control Conference, St. Louis, Mo., Nov. 10 1949. Numbers 1-55 refer to items listed in References at end of paper.

chaser as the vendor's affidavit as to the particular values of the product delivered.

It might be expected that federal procurement agencies would take the lead in requiring adherence by the manufacturer to quality control or particular inspection methods, in view of the long and well established policy of such agencies to purchase only on specifications setting the standard or level of quality and to inspect "rigidly" to determine compliance with the specifications.[10] Tolerances are specifically stated, and the percentage of allowable defectives is not left to future negotiation. In 1941 it was announced as the procedure of the Treasury Department's Procurement Division that "Rigid examination of deliveries prior to acceptance and payment was the vital and concluding step of procurement."[11] And occasionally it was necessary to send inspectors to inspect in the process of manufacture. Where such measures are taken to assure compliance with quality standards, it seems but one step, and an entirely logical one, to require the supplier to maintain a system of quality control. I am advised, however, that while the Quartermaster Corps, for example, desires that contractors maintain efficient inspection systems so that their product will have a reasonable chance of being accepted, there is no specific requirement to that effect in the contracts.[12] Presumably, however, the sampling tables in use by the Government are known by suppliers, and they can govern their own inspection procedures so as to meet the tests to be given by the Government.[13] While particularity in the drafting of contracts reduces the areas of disagreement over interpretation,[14] it may also of course involve a sacrifice in flexibility, and private purchasing departments are likely to object to too much emphasis on the negotiation and contract-drafting phases of the purchasing function.[15]

A case[16] presenting a conflict of evidence as to compliance with specifications involved bricks to be used in a construction project in Jarboesville, Md., erected during the war at the instance of the National Housing Agency. The Goevrnment specified in its contract the use of "new common brick made from clay or shale [to] comply with A.S.T.M. Specification C 62-41T, Grade MW." The general contractor subcontracted the masonry work, and the subcontractor ordered bricks in accordance with the specification from the Baltimore Brick Co. The American Society for Testing Materials specification referred to prescribes the method for sampling and testing. Thereunder the purchaser appoints a competent person to select representative bricks at a place designated at the time of the purchase order. The only test made for determining the quality of the brick furnished by the Baltimore Brick Co. was with bricks selected by the Project Engineer more than a month after the purchase order was placed and after the selected bricks had lain exposed to winter weather with alternate freezing and thawing for a least twenty days and probably longer. The Bureau of Standards tested the bricks so selected and found the compressive strength of three out of twelve to be below the allowable individual minimum of 2200 pounds per square inch. If this test was acceptable, it indicated a breach of express warranty, which is the legal terminology denoting a failure to keep a material promise affecting the goods. But the courts, both trial and appellate, declined to accept the test. Both courts were impressed with the evidence of the brick company, which was suing the contractors for the purchase price of the bricks, that bricks exposed to winter weather, as were those from which the samples were selected, absorb moisture and lose compressive strength.

What evidence did the brick company have that its bricks did meet specifications? The only evidence it could offer was of tests made in 1936, over 7 years before the controversy here arose, and in 1945, almost a year after the delivery of the bricks involved in the controversy. The 1945 tests were made by a reputable Baltimore firm of chemical engineers and analysts and they showed the ASTM tests to be met by the brick company's product. The counsel for the contractors objected strenuously to the introduction of evidence of tests of samples of bricks made before and after those involved in the litigation, but the evidence was admitted for what it was worth. The court was satisfied that the company, a well established brick manufacturer in Baltimore, had been carrying on a standard type of brick manufacture and that while there was "no absolute certainty in the evidence that these samples were identical with the brick . . . actually delivered," still there was no convincing proof that the court should not treat them as being of the same character and condition. The court thought that, of the samples taken, those tested for the brick company were taken under conditions more closely approximating those specified in the contract. Moreover, the burden of proof was on the purchaser alleging the breach of warranty. So the brick company collected from the contractors, who had been compelled by the Government to tear down certain work that had been completed with the Baltimore Company's bricks. The real difficulty seems to have been that the Government had specified the wrong type of brick for so rigorous a climate.

Another recent case of interest here is *Whitin Machine Works v. United States.*[17] The plaintiff, United States, through the Maritime Commission, during the war ordered a large number of generator sets from Whitin for installation on Liberty ships to supply electricity for lights and auxiliary equipment. The sets were installed on the ships by the shipbuilders, not Whitin. Performance specifications were included in some detail in the contract, but the only specification as to materials was that they should be in accordance with accepted commercial practice. On the maiden voyage of a ship on which one of these generator sets was installed, the ship's lights went out, the engine driving the generator speeded up greatly, and the flywheel burst apart, injuring two members of the crew. They collected over fifty thousand dollars from the United States as damages for the injuries resulting from the unseaworthiness of the generator set. The United States in turn sued Whitin for breach of an implied warranty that the flywheel was free from any latent defect. The flywheel was made of cast iron mixture, in accordance with accepted commercial practice; the defect suggested by the Government's evidence was excessive porosity, which reduces the bursting speed required to cause a failure. The Government's evidence was testimony of a metallurgist of the American Bureau of Shipping who had examined pieces of the fractured flywheel. Whitin's rebuttal testimony showed that Whitin made daily tests—in fact three or four

tests a day—of samples taken from the melts of metals that went into the flywheel castings, to determine the chemical ingredients and breaking strength of the material. Records of the tests for the period during which the flywheel in question was manufactured showed "no appreciable deviation from . . . standard practice." These daily tests showed that the iron from which the wheel was made had a tensile strength sufficient to enable it to withstand speeds over seven times that stated as normal when the unit was operating at full power. Moreover the tensile strength was 40% greater than required by the American Bureau of Ships' Manual. Finally a running test had been given the generator set by a Maritime Commission representative after its installation, and it was found satisfactory. The trial court nevertheless found Whitin liable for breach of implied warranty or promise that the wheel contained no defects.[18] On appeal, the Court of Appeals, assuming that certain warranties might be implied under the circumstances, nevertheless held that there was no breach. Even a little excessive porosity, as testified to by the Government's metallurgist, was said not to render it unmerchantable or not reasonably fit for the particular purpose for which it was required. The fact that the flywheel disintegrated at a speed immensely higher than contemplated could not be a basis for liability, and judgment for the United States in an amount over $75,000 rendered by the court below was reversed.

The relevant testimony for Whitin in this case was rendered by the vice-president of the company, who was an engineer with considerable experience in foundry work.[19] No objection was made to his testimony by the Government's counsel. The trial court pointed out that his testimony as to the results of certain laboratory tests by a Professor Benjamin might have been objected to as heresay.[20] But the Court of Appeals referred approvingly to the vice president's evidence[21] and was apparently influenced by it in coming to its decision.

In an old Massachusetts case,[22] where the plaintiff was suing for the purchase price of 4,972 spokes sold to the defendant, the defendant sought unsuccessfully to introduce testimony of persons who had selected 40 or 50 of the spokes as a fair sample in appearance and quality of the whole lot. The Supreme Judicial Court declined to review the trial judge's exclusion of the proffered testimony in the absence of a full report of the facts underlying the ruling and of a showing of clear error.[23] The trial judge was said to be justified because of a failure to establish the fairness of the sample. Moreover, it was noted that the persons who selected the sample were not shown to be experts or competent to form an opinion as to the comparative quality or value of the lot selected and the remainder of the spokes.

SAMPLING FOODS, DRUGS, AND COSMETICS

A manufacturer may be obliged not only by his contracts and the law governing contracts and sales to meet certain quality specifications and standards; if he is a manufacturer of food, drugs, or cosmetics, he is subject to the requirements imposed by and under federal and state legislation. The Federal Food, Drug, and Cosmetic Act of 1938[24] is the most complete and advanced example of this legislation. State legislation is necessary to supplement federal regulation because the latter can be exercised only when the product has become involved in some way with interstate or foreign commerce or is manufactured within a territory of the United States. The courts are quick to find an interstate feature on which to hang federal jurisdiction,[25] and it is practically impossible for any manufacturer of food, drugs, or cosmetics, if his production is substantial, to escape federal control.

The Act of 1938 is mainly directed at the evils of adulteration and misbranding of foods, drugs, devices, and cosmetics. Violations of the Act may be enjoined by federal courts, may be punished by fine and imprisonment, or may be the basis for seizure and condemnation of offending articles.[26]

Of course many technical problems are presented in determining whether a food, drug, device, or cosmetic meets the requirements of the Act. Enforcement techniques have undergone considerable change in the last half century as methods of production and methods and the scope of regulation have changed. Inspection has moved from simple physical examination of a few products through chemical analysis of many to factory inspection.[27] The process of seeking out violations by collecting extensive numbers of samples was wasteful because it required collection and examination of many samples to detect a few violations.[28] This procedure, called the objective procedure, was subject to the more fundamental objection that discovery of violations occurred after distribution of the product, thus making effective protection of the public, even from products discovered to be in violation, very difficult if not impossible. Moreover, because of the limited inspection force to cope with the increasing number of products and dealers, adequate coverage was impossible and enforcement discriminated against those few who were found to have violated. Realizing the necessity of detecting violations at the point of production, Chief Inspector W. G. Campbell[29] very early in the administration of the Food and Drug Act of 1906 instituted an intensive training course in factory inspection technique.[30] While the old Act of 1906 did not authorize factory inspections, they were rarely refused by the manufacturers. Consequently, when the Act of 1938 authorized factory inspection,[31] it was sanctioning what had already become established practice. Factory inspection serves the primary purpose of obtaining evidence for law enforcement, although it also serves corrective and educational ends. Inspectors are under instructions to obtain comprehensive information concerning interstate distribution of the factory's products, so that if violations are encountered or suspected, official samples can with facility be collected and examined.[32] Consistently, with the limitations of the Act, official samples can be collected for examination and investigation only if taken from a shipment which has been delivered for introduction into interstate commerce, is in or was received in such commerce, or was manufactured within a territory of the United States.[33]

While samples may be used in evidence in criminal prosecutions and proceedings for injunctions, questions concerning the sampling procedure used by Food and Drug Administration officials arise most often in seizure and condemnation proceedings. Although the Act authorizes the condemnation only of "Any article . . . adulterated or mis-

branded,"[34] the Food and Drug Administration has sought to seize and condemn entire shipments of products on the basis of inspection of samples.[35] This practice has generally been sanctioned by the courts, so that it is not necessary for the inspector to check every can or package or even every case.[36]

When the ground for seizure is adulteration on account of the presence of a "filthy, putrid, or decomposed substance," another problem in statutory interpretation is presented. Since a food, drug, or cosmetic is deemed adulterated "if it consists in whole or in part" of such a substance,[37] the question is whether a few, many, or all of the samples examined must show adulteration. Judge Learned Hand construed "in part" to require that filth, for example, be present in a substantial degree, but conceded that the requirement might under some circumstances be met "even though the filth was present to a degree that can be observed only under a microscope."[38] It seems clear, however, that the statutory language does not require every can or package to contain filthy, putrid, or decomposed matter;[39] ergo, not every can or package sampled need be shown to offend under the Act in order for condemnation of the whole shipment to be ordered. Thus, in a salmon case, involving 1974 cases,[40] analysis of samples showed that nearly one-fifth of the product analyzed was putrid or tainted, and approximately one-fourth putrid, tainted, or stale. The canner argued that the court should not destroy 1600 cases of good salmon because 400 cases of the same lot were found to be adulterated. Under a provision of the statute[41] the canner was allowed to have the salmon restored to it on putting up a bond not to put it back in commerce unless brought into compliance with the Act. It was up to the canner to select the good from the bad if he wished to save it.[42]

The most liberal interpretation of the Act from the viewpoint of the Government is that involving 43½ gross, more or less, rubber prophylactics labeled "Xcello's Prophylactics," and 112½ gross, more or less, rubber prophylactics labeled "Silver-Tex Prophylactics."[43] Tests made by the Government showed an average of 7.37% to be leakers. The claimant objected to condemnation of the 20,000 prophylactics presumed to be good. The court allowed the claimant to have them under a bond to select the good from the bad. The claimant complained that reinspection would render them useless or impair their quality or strength. The court's answer: That's too bad. But the Act forbids the sale of articles labeled as prophylactics when they are not in fact. Besides the manufacturer contended that he has the most modern inspection and testing methods known in this particular trade. Why cannot the articles be tested again?

How much of a sample must the Government take before it may be called adequate? In the prophylactic case, two sets of samples were taken. In taking post-seizure samples, the Government took one dozen articles from each of thirty-six gross cartons of Xcellos, and from the three gross so selected seventy-two samples were taken at random. Six, or about eight percent of the seventy-two, were found to be defective. In a pre-seizure test of the Xcello brand, 108 were selected and eight were found to be defective, again about eight percent. The post-seizure samples of the Silver-Tex brand were obtained by substantially the same method of selection as in the case of the Xcellos. Here 120 samples were taken, and four, or 3.3%, were defective, or approximately 11.11%. The average defects, therefore, of all the tests approximated 7.37%. Over 22,000 rubbers were involved, 408 samples were tested—1.8% of the total, and altogether 30 were found to be defective, a little over 1/10 of 1% of the total; and that was enough to cause the whole shipment to be condemned, subject to the claimant's right to cull out the leakers. The Court of Appeals of the Eighth Circuit rejected the contention that the samples were not representative of the shipment."

Recently an entire interstate shipment of 935 cases of tomato puree was condemned on the basis of an examination of "several samples," even though the shipper was able to show that different cases or cans were marked so as to indicate different dates of canning.[45] Said the court, "If the samples are reasonably representative of the lot shipped,—that is, taken at wide random from the entire shipment it is in my opinion sufficient to embrace the entire shipment in the condemnation."[46] The concept of the original shipment as the universe to be sampled is apparently regarded as basic by the Food and Drug Administration, and a suggestion that different batches in a single shipment, run off in different production cycles, be treated as different universes for sampling would probably be treated as impractical.[47a] One court, however, in ruling against the United States on the facts as well as the law, emphasized the importance of evidence of identity of conditions of production of a number of cans if they are to be treated as a unit for the purpose of the Act, and insisted on the necessity of careful sampling with reference to the conditions of production of the several cases of a shipment.[47] In any event, it is clear that the issue of whether a sample is fairly representative of the whole lot or shipment is one of fact,[48] which may be determined by the jury if one is demanded pursuant to the Act.[49] Hence competent evidence relevant to that issue would be admissible.

It has been reported that the Food and Drug Administration takes the legal position that *every package* of any food must comply fully with any standard of quality established under Section 401 of the Act.[50] However, surely a standard may, and no doubt in some cases should, be established which requires only that the average of a prescribed sample should comply. In the establishment of any standard, the unit of product to which the standard is to be applied—i.e., whether each package or the average of a prescribed quantity is to be measured—should be made clear.[51] The problem of determining what standard shall be established under Section 401 involves the same kind of balancing of considerations (though perhaps not the same considerations) as that confronting engineers and industrial planners in the formulation of specifications in a manufacturing plant. If the food standard is too high, the cost of compliance may force the price beyond the reach of most consumers or reduce the quantity produced and marketed to undesirable proportions.[52]

The Food and Drug Administration does not adhere to any particular sampling plan.[53] In checking for economic violations, such as short weight, larger samples are required than in the case of adulteration in the form of decomposition or filth.[54] The size of the sample may vary de-

(Continued on page 30)

PREVIEW OF THE
Fifth Annual Convention
American Society for Quality Control

Cleveland Municipal Auditorium, Cleveland, Ohio

Wednesday and Thursday, May 23-24, 1951

TO INSURE ample accommodations for the program, activities, and attendance planned for the Fifth Annual ASQC Convention, the entire available capacity of the Cleveland Municipal Auditorium has been engaged for both days of the Convention.

In this issue the technical program of the Convention is presented in outline form to assist members in planning attendance at the Convention and to help them in making the Convention known to non-members. More detail concerning the technical program and the other events of the Convention will be presented in the March and May issues of the magazine.

The purpose of the Technical Program is to present a story of Quality Control in 1951 which is sufficiently broad to attract all levels of members and potential members; from at least the major fields of interest; from the management as well as the operating point of view; from the frontiers of principle and practice to an educational program introducing the subject.

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- Quality Control in Non-Metallic Fields
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- Management's View of Quality Control
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- Visual Aids to Presenting Quality Control in the Factory

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Paralleling the work done at the Milwaukee Convention, a complete elementary presentation of the principles and practices of Quality Control will be available for those to whom the subject is new as well as for those who wish further groundwork in the fundamentals.

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- The Armed Services' Use of JAN 105 A
- The Armed Services and the Quality Control Departments of Prime Contractors and Sub-Contractors
- The Latest in Acceptance and In-Process Sampling

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A presentation of the services of mathematical statistics to Quality Control.

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- Applications of Statistics to Chemical Problems in Industry
- Applications of Statistics in Pharmaceutical Manufacture

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- Quality Control in Assembly Plants

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- Control of Steel Processing
- Control of Metal Fabricating
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To All A.S.Q.C. Members and Friends:

Keeping pace with the extremely rapid expansion of the entire Quality Control field, and the resultant interest on the part of more and more individuals from an ever-widening field, the Fifth A.S.Q.C. Convention Committee has been hard at work for several months designing a Convention to meet popular demand at a National level. Every effort has been made to incorporate into the entire affair the reactions of conferees, exhibitors, and guests at the Milwaukee Convention last year.

The Cleveland Public Auditorium has facilities which are among the finest in the country, and full advantage will be taken of these. The main arena has been laid out to accommodate sixty-three attractively decorated exhibit spaces and concurrently seat 1,500 people at the luncheons and banquet. As this is written many of the exhibit spaces have already been reserved.

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pending on the amount of knowledge the Administration already has about the product being tested. I am advised by L. D. Elliott, Associate Commissioner of Food and Drugs, that few plants inspected by the Administration employ statistical quality control chart procedures. As yet these systems are not prevalent enough, he reports, to allow the Food and Drug Administration to make use of their advantages in inspection techniques.[55]

Editorial Note: Professor Kennedy's paper will be concluded in the March 1951 issue of IQC, including a Supplementary Note covering material that has become available since November 1949.

References

1. Published in 1928.
2. See, e.g., Simpson & Field, Social Engineering Through Law, 22 N.Y.U.L. Q. Rev. 145 (1947).
3. Loevinger, Jurimetrics—The Next Step Forward, 33 Minn. L. Rev. 455 (1949).
4. Published in 1945.
5. See, e.g., pp. 1-3, 18-23, 58-72, 209-12.
6. Cf. Statistical Quality Control, Fortune, Dec. 1949, p. 167, where it is reported that such diverse companies as Ford, Sheaffer Pen, and Aldens exert "steady pressure" on suppliers to institute statistical quality control.
7. A letter from Arthur L. Lipman, Industrial Specialist with the Quartermaster Research and Development Laboratories, dated Oct. 27, 1949, verifies that statistical quality control is having a "terrific impact" on the nature of Government specifications.
8. See the abstract of his paper on Manufacturing Control of Soaps and Toiletries, delivered at the Fourth Annual Midwest Quality Control Conference, St. Louis, Mo., Nov. 10, 1949.
9. Letter dated Sept. 30, 1949. The effect of such a certificate may be to protect the purchaser after acceptance in the event the product fails to meet specifications. Cf. Juran, Management of Inspection and Quality Control 138 (1945); Lewis, Industrial Purchasing 169-70 (1940).
10. Kaidanovsky & Edwards, Consumer Standards 260, 269 (TNEC Monograph 24, 1941).
11. Id. at 260.
12. Letter from Arthur L. Lipman, cited supra note 7.
13. Mr. Lipman reports in the letter cited in note 7 that "The Quartermaster Corps uses for their own inspection a set of tables developed by the Columbia Research Group for the U. S. Navy, which presently is called JAN Standard 105—Sampling Tables for the Inspection of Attributes."
14. Juran observes: "It is the exception rather than the rule for a material specification to define the sampling procedure in a way which avoids subsequent debate. In many instances the materials engineer is not aware that he must choose between a specification for the lot or a specification for any piece taken from that lot. If his specification is for the lot, his sampling procedure must define sample sizes, averages, etc., in a way statistically complete. The art of writing specifications has far to go in this respect." Management of Inspection and Quality Control 137 (1945).
15. Cf. 2 National Ass'n of Purchasing Agents, Handbook of Purchasing Policies and Procedures 115 (1942).
16. John A. Johnson & Sons, Inc. v. United States to Use of Baltimore Brick Co., 153 F. 2d 534 (4th Cir. 1946).
17. 175 F. 2d 504 (1st Cir. 1949).
18. United States v. Whitin Machine Works, 79 F. Supp. 351 (D. Mass. 1948).
19. Transcript of Record, p. 118 et seq.
20. Id. at 131.
21. 175 F. 2d at 508. See also Kirchick v. Silverman, 76 N.Y.S. 2d 75 (N. Y City Ct. 1947), considering favorably expert's testimony as to tests and examination to which glass jars were subjected before leaving Beech-Nut Packing Company.
22. Brown v. Leach, 107 Mass. 364 (1871).
23. In the ordinary case the fairness of a sample is a question of fact, not of law. See note 48 infra. However, a judge passes on the admissibility of evidence to be considered by the jury, and that function may necessitate the determination of a preliminary question of fact. If he desires, the judge may, but need not, submit such a question to the jury. Wm. M. Galt & Co. v. United States, 39 App. D. C. 470 (1913) cf. Lake v. Clark, 97 Mass. 346 (1867).
24. 52 Stat. 1040 (1938), as amended, 21 U.S.C. c. 9 (1946), as amended.
25. See e.g., United States v. Sullivan, 332 U. S. 689 (1948).
26. These three sanctions are provided for in §§302, 303, and 304 respectively.
27. Wharton, Original Federal Food and Drugs Act of June 30, 1906 as Amended: Its Inspection Evolution, 1 Food, Drug, Cosmetic L. Q. 348 (1946).
28. It appears from a recently published series of articles that local authorities have been experiencing difficulties in carrying out the provisions of the English Food and Drugs Acts relative to taking samples of milk. See 111 Just. P. 157, 546, 567, 705 (1947).
29. Later Chief of the Food and Drug Administration.
30. Wharton, supra note 27; at 357-8. See also McKinnon, Field Observations on Food, Drug and Cosmetic Law Enforcement, 2 Food, Drug, Cosmetic L. Q. 302, 305-8 (1947).
31. §704. See also §§301(f) and 303(a).
32. White, Sellers & Grundstein, Administrative Procedure and Practice in the Department of Agriculture under the Federal Food, Drug, and Cosmetic Act of 1938, p. 248, reprinted in Toulmin, The Law of Food, Drugs and Cosmetics 721 (1942).
33. 21 Code Fed. Regs. §1.700(a)(1) (1949). Samples of imported articles may also be obtained by Food and Drug Administrative representatives pursuant to the enforcement of §801 of the Act. Such samples are obtained on request to the collector of customs or the appraiser of merchandise. White, Sellers & Grundstein, supra note 32, at 252-3, reprinted in Toulmin, supra note 32, at 724. Such samples, however, seem not to be referred to as official samples. See 21 Code Fed. Regs. §§1.302, 1.305 (1949).
34. §304(a).
35. In the light of this position and the practice of the Administration, a statement of W. G. Campbell, the former Chief of the Administration, in opposition to the incorporation of a proposed amendment in one of the bills that eventuated into the Act of 1938, is interesting. The proposed amendment required the Secretary of Agriculture to provide a part of any official sample of a food, drug, or cosmetic for independent or joint check examination by the manufacturer or distributor named on the label; a modified version of the proposal was incorporated as §702(b) into the Act of 1938. Mr. Campbell pointed out that where the composition of the product is not uniform, examination of a subdivision by the manufacturer would yield analytical results different from those obtained by the Government. Then he noted that non-uniformity would be charactertistic of all food and drug products that are adulterated because consisting partly of filthy material, of perishable products susceptible to decomposition, and of certain others. Nevertheless, as is apparent from reference to the cases cited in notes 36-45 infra, the Government has proceeded on the assumption that a sampling of such products justifies condemnation of entire shipments. Hearings before a Subcommittee of the House Committee on Interstate and Foreign Commerce on H.R. 6906, H.R. 8805, H.R. 8941, and S. 5, 74th Cong., 1st Sess. 752-3 (1935), reprinted in Dunn, Federal Food, Drug, and Cosmetic Act 1235, 1309-10 (1938).
36. Holding that "article" comprehends the entire shipment seized rather than each individual container or package: A. O. Andersen & Co. v. United States, 284 Fed. 542 (9th Cir. 1922), rev'g United States v. 1,974 Cases of Canned Salmon (W.D. Wash. 1922), printed in Decis. of Cts. in Cases Under the Fed. Food and Drugs Act 1037 (White & Gates ed. 1934), hereinafter cited as F & D Act Decis; United States v. 2,205 Cases of Canned Salmon, F & D Act Decis. 1133 (W.D. Tex. 1925); United States v. 496 Cases of Canned Salmon, F & D Act Decis. 1099 (E.D. Mo. 1924). But see United States v. 200 Cases, More or Less, 289 Fed. 157 (S.D. Tex. 1923); United States v. 1,459 Cases of Canned Salmon, F & D Act Decis. 995 (W.D. Wash. 1921); cf. United States v. Direct Sales Co., 252 Fed. 882 (W.D. N.Y. 1918) (holding the shipment of seven different medicines, each of which was both adulterated and misbranded, to result in 14 violations).
37. See §§ 402(a)(3), 501(a)(1), and 601(b). Section 7 (5) of the Act of 1906, 34 Stat. 770, was to the same effect but limited in application to food and drugs.
38. United States v. 408 Bu. of Oysters, F & D Act Decis. 718, 720-1 (S.D.N.Y. 1916). Cf. United States v. 496 Cases of Canned Salmon, F & D Act Decis. 1099, 1105 (E.D. Mo. 1924).
39. See United States v. 2,205 Cases of Canned Salmon, F & D Act Decis. 1133, 1135 (W.D. Tex. 1925).
40. A. O. Andersen & Co. v. United States, 284 Fed. 542 (9th Cir. 1922).
41. Now § 304(d).
42. In another salmon case, United States v. 200 Cases, More or Less, 289 Fed. 157 (S.D. Tex. 1923), testing by the Government, whose inspectors apparently used the smelling method (this was in 1923), showed 18% of the product to be filthy, putrid, and decomposed. The claimant offered its own witnesses who had made chemical tests and found no evidence of decomposition and also served some of the cans' contents as food without harmful result. The claimant objected to the uncertainty of the Government's testing method and that the Government's proof was not sufficient to justify condemnation of cans not found to be bad on testing. The court was inclined to agree and to compel testing of every can; however, since the court was satisfied that the labeling of the cans as "Fresh Fish" was false and misleading as to all cans, it allowed condemnation of all and forbade release of any to commerce until the good had been separated from the bad.
43. United States v. 43½ Gross Rubber Prophylactics, 65 F. Supp. 534 (D. Minn. 1946), aff'd sub nom. Gellman v. United States, 159 F.2d 881 (8th Cir. 1947).
44. In A. O. Andersen & Co. v. United States, 284 Fed. 542 (9th Cir. 1922), cited supra note 40, involving 1,974 cases of canned salmon, 408 cans were selected at random from 408 of the cases, but results were available only as to 384 cans. The cans were divided into two equal lots of 192 each. In the first, 36 putrid cans and 19 stale cans were found. In the second, 36 putrid cans and 12 stale cans were discovered. The court held that the proof went far enough that it might satisfy a court or jury that the adulteration extended to the whole product sought to be condemned, and it reversed a directed verdict for the defendant based on the notion that every can condemned must be shown to be bad.

    In the United States v. 430 Cases of Canned Salmon, F & D Act Decis. 1035 (E.D.S.C. 1922), Government sampling and examination indicated that 12% of the shipment was "bad" and 25-30% more was stale. Under court order a can was taken from every 43d case, or ten cans in all, to be submitted to a chemical expert for independent examination. The laboratory agreed upon by the parties reported the contents of the ten cans to be of sound quality. Nevertheless the court ordered the entire lot condemned because it was unwilling to disregard the results of the Government's examination, which included a substantially larger sample and "was of a more extended and careful character than that given otherwise." Id. at 1037.
45. United States v. 935 Cases, More or Less, 65 F. Supp. 503 (N.D. Ohio 1946). The court rejected the canner's contentions that: (1) tomato puree cannot, even under the most careful supervision escape entirely having some mold, rot fragments, etc.; (2) the senses of smell and taste are more dependable in detecting rot than the microscopic procedure

adopted by the Government. As to the first, the court simply referred to the statute, which tolerates no filthy, putrid, or decomposed substances, but also noted that tolerances adopted by the Administrator for enforcement purposes had been exceeded by the puree involved. As to the second contention the court emphasized the greater variability of the results to be expected from application of smell and taste tests than from microscopic procedures, which are the most reliable we yet have. Of course the witnesses who conduct such tests are subject to cross-examination and their credibility is for the finder of the facts.

46. Id. at 504. Cf. Origet v. Hedden, 155 U.S. 228 (1894), involving a challenge by an importer to the sampling by appraisers in determining the value of certain imported goods.

46a. But see testimony of W. G. Campbell, then Chief of the Food and Drug Administration, at Hearings Before a Subcommittee of the Committee on Interstate and Foreign Commerce, House of Representatives, on H.R. 6906, H.R. 8805, H.R. 8941, and S. 5, 74th Cong., 1st Sess. 88 (1935), reprinted in Dunn, Federal Food, Drug, and Cosmetic Act 1235, 1264 (1938), suggesting that under certain circumstances a system of coding might be useful in the isolation of the product of a single day's operation during which a temporary objectionable production condition had resulted in adulteration.

47. United States v. 1,459 Cases of Canned Salmon, F & D Act Decis. 995, 996 (W.D. Wash. 1921).

48. A. O. Andersen & Co. v. United States, 284 Fed. 542 (9th Cir. 1922); United States v. 2,995 Cases of Canned Salmon, F & D Act Decis. 1136 (W.D. Wash. 1925); United States v. 1,500 Cases of Tomato Pulp, F & D Act Decis. 892 (S.D.N.Y. 1918); United States v. 408 Bu. of Oysters, F & D Act Decis. 718, 721 (S.D.N.Y. 1916); United States v. John A. Tolman & Co., F & D Act Decis. 78 (N.D. Ill. 1909); United States v. Golden & Co., F & D Act Decis. 1033 (Police Ct. D.C. 1922) (criminal prosecution). Cf. Wm. M. Galt & Co. v. United States, 39 App. D. C. 470 (1913).

49. ". . . on demand of either party any issue of fact joined in any such case (i.e., of seizure) shall be tried by jury." § 304(b). It is to be noted that the case cited in note 45 supra was tried to the court without a jury; hence the court found the facts in addition to declaring the applicable law.

50. Austern, The Formulation of Mandatory Food Standards, 2 Food, Drug, Cosmetic L. Q. 532, 569-70 (1947). Austern adds that "Realistically, it is doubtful whether seizure for misbranding occurs where only one unit among many is found defective."

51. The formulations of standards of quality for a few food products require the examination of a number of samples. Thus, in testing pitted canned cherries a number of containers must be taken at random until a total quantity of contents of at least 24 pounds has been obtained. 21 Code Fed. Regs. § 27.31(b)(1) (1949).

52. See United States v. 298 Cases, CCH Food Drug Cosmetic Law Rep. ¶7131 (D. Ore. 1949).

53. The statements in this paragraph are based on information supplied in a letter from L. D. Elliott, Associate Commissioner of Food and Drugs, dated Nov. 1, 1949. Cf. note 51 supra. An article by Knudsen on Sample Size of Parenteral Solutions for Sterility Testing, in the preparation of which officials of the Food and Drug Administration furnished "active cooperation and assistance," appears in 38 J. Am. Pharm. Ass'n at 332 (June 1949). "The inescapable conclusion is reached that since there is no reason to be more lenient with a small lot than with a large lot, the sample size taken must be approximately the same regardless of lot size." Id. at 337.

54. W. G. Campbell, when Chief of the Food and Drug Administration, stated before a House subcommittee in 1935 that in the sampling of large consignments of canned goods to determine the presence of filthy or decomposed material, the manual of instructions required the inspector to procure one or more cans from cases throughout the stock. "The number of cases so sampled must at least equal the square root of the total number." Hearings Before a Subcommittee of the House Committee on Interstate and Foreign Commerce on H.R. 6906, H.R. 8805, H.R. 8941, and S. 5, 74th Cong., 1st Sess. 753 (1935), reprinted in Dunn, Federal Food, Drug, and Cosmetic Act 1235, 1310 (1938).

55. See note 53 supra.

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APPLICATION—CHEMICAL INDUSTRY

THE DESIGN & INTERPRETATION OF INTERLABORATORY TEST PROGRAMS; Grant Wernimont, Eastman Kodak Co., Rochester, N.Y.
(ASTM Bulletin, No. 166, May 1950)

Many chemical test methods are quite complicated and require careful planning to get consistent results in different laboratories. This paper is a discussion of the preliminary draft of a report on "Planning an Interlaboratory Study of a Test Method." Control chart methods of examination and interpretation of data are among those recommended.

INDUSTRIAL APPLICATIONS OF STATISTICAL METHODS—CORRELATION ANALYSIS; J. N. Robinson and H. L. Williams, The Consolidated Mining and Smelting Company of Canada, Ltd.
(Chemistry in Canada, v. 2, n. 1, Jan. 1950, p. 27)

Application of correlation analysis to certain chemical investigations. This article includes methods for calculating correlation coefficients, lines of regression, and confidence limits. Examples given are for correlation between operating voltage and for correlation between absorption coefficient and temperature for gas scrubbers in a nitric acid plant.

APPLIED MATHEMATICS SAVES RESEARCH TIME AND MATERIALS; W. L. Gore.
(Chemical Industries, v. 66, n. 5, May 1950, p. 678)

A brief discussion of the value of certain statistical concepts such as a test for significance, factorial design, Latin squares, and other methods of confounding various effects.

APPLICATION—METAL WORKING

BETTER WELDMENTS THRU TAILORED QUALITY CONTROL; Orville J. Barnett, Metal & Thermit Corp.
(Steel, v. 126, n. 121, May 22, 1950)

A discussion of the essentials of good weld design and a procedure for inspection of same. No statistical methods mentioned.

APPLICATION—MISCELLANEOUS

CONTROLLING QUALITY BY SAMPLING PLANS; Walter F. Blickle, Chief Inspector, Quality Control Division, A. O. Smith Corp., Kankakee Works.
(Industrial Sheet Metal, v. 2, n. 11, Aug. 1950, p. 5)

Mr. Blickle describes the use of Dodge and Romig sampling plans at the A. O. Smith Corp. These plans are used in receiving inspection with explanation to vendors of the plan used for their items. Quality Control applications in the press room, final inspection of tank welding, and in the demerit charts for final inspection are described.

GRAPHIC INSPECTION METHOD PIN-POINTS ERRORS IN MACHINED PARTS; Fred Bohle, Chief Engineer, Illinois Tool Works, Chicago.
(Steel, v. 126, n. 12, March 20, 1950, p. 85)

Explains how automatic recording of inspection instrument readings is proving valuable in checking gears and other parts with complex surfaces. Recording saves inspection time; gives accurate, permanent records which can be quickly interpreted to locate causes of error. Charts of mating gears and their cutting tools can be superimposed and matched.

OPPORTUNITIES FOR QUALITY CONTROL IN THE FLAT GLASS FIELD; F. L. Bishop and F. W. Mowrey, American Window Glass Co., Arnold, Pa.
(Glass Industry, v. 31, n. 6, June 1950, p. 302)

Applications of quality control to the various problems and processes in the glass industry are presented in a general discussion of their value as tools to obtain and analyze data and to determine "that elusive factor, the assignable cause."

LIFT OUTPUT THROUGH QUALITY CONTROL; C. W. Kennedy, Quality Control Engineer, Federal Products Corp., Providence, R.I.
(Steel, v. 127, n. 15, Oct. 9, 1950, p. 86)

A summary of various quality control applications by a number of companies in the country. Illustrated with charts and photographs.

ENGINEERING & EXPERIMENTS

THE RELATIONSHIP BETWEEN ENGINEERING & INSPECTION; Charles B. Johnston, Chief Engineer, Pittsburgh Equitable Meter Division, Rockwell Manufacturing Co., Pittsburgh, Pa.
(Instruments, v. 23, n. 4, April 1950, p. 358)

This article discusses the similarities and mutual problems of the Engineering and Inspection Departments in industry. Their mutual interdependence as well as sources of conflict are noted. As Mr. Johnston states, "we are 'stuck' with both of them", and so attempts at mutual understanding between these two important functions are necessary to develop the full cooperation required in modern industry.

STATISTICAL ENGINEERING
(The Technical News Bulletin of the National Bureau of Statistics, v. 34, n. 3, March 1950)

Statistical Engineering is defined as "that phase of scientific research in which statisticians advise, guide, and assist other scientists in the conduct of experiments and tests." The function of the Statistical Engineering Laboratory of the National Bureau of Standards is described. Description of some of the statistical services rendered are given. These include Statistical Methodology, Acceptance Inspection, Process Control, Designing of Experiments, and Sampling.

QUALITY CONTROL & ENGINEERING SPECIFICATIONS; J. Manuele, Westinghouse Electric Corp.
(Standardization, v. 21, n. 8, Aug. 1950, p. 198)

This article discusses the need for clearly defined, understandable, and measurable standards of quality as one of the requirements of a good quality control program. Suggestions are made for the establishment of realistic engineering tolerances. Also a procedure for verifying the engineering specifications by statistical methods is given. Examples cited include studies of:

Rivets from two suppliers,
Machinability of certain gray iron castings,
Size of cotton yarn for insulation.

GRAPHICAL ESTIMATION OF INSPECTION ERRORS; F. Levi, Research and Design Engineer, Rola Co.
(The Engineer (British), v. CXC, n. 4928, July 7, 1950, p. 2)

A problem arises when a quality characteristic is measured by instruments which are subject to error, or when, by correlation, one characteristic is judged by measurement on another characteristic. The author discusses graphical methods for estimating the approximate percentage of faulty articles accepted and of satisfactory articles rejected in such cases. Illustrations with many graphs.

MANAGEMENT AND PERSONNEL

INSURE SUCCESS FOR YOUR QUALITY CONTROL PROGRAM; J. M. Juran, Chairman, Department of Administrative Engineering, N.Y.U.
(Factory Management & Maintenance, v. 108, n. 10, Oct. 1950, p. 106)

Mr. Juran very frankly discusses certain factors involved in the success or failure of the quality control programs of 39 companies.

The factors analyzed are:

1. Definition of Program
2. Adequacy of Budget
3. Technical Competence of Engineers
4. Adherence to Objective
5. Managerial Competence of Program Head
6. Level of Shop Participation

A chart that graphically shows the relative effects of each factor is given. This chart is based upon the consideration of the degree of each factor present in each of the 39 cases.

This article can be of real value in the analysis of the prospects and needs of any particular quality control program. It can provoke much valuable thought on the part of those interested in, or developing, a quality control program.

MISCELLANEOUS

3RD ANNUAL QUALITY CONTROL FEATURE ISSUE
(Tool & Die Journal, v. 16, n. 7, Oct. 1950)

This issue of the Tool & Die Journal contains numerous features and short articles on Quality Control. These include:

"Quality Control's March of Progress," W. R. Weaver

"Tools and Dies Determine Quality," J. Manuele

"Organizing the Quality Control Program," D. J. Greb

"Vendor Quality Classification," Roscoe Smith

"Statistical Sampling Inspection in Aircraft Parts Industry," W. H. Coughlin

"Quality Control in Carbides Tool Manufacturing," D. F. Dickey

"How Jig Borers & Jig Grinders Can Inspect Their Own Work," R. F. Moore

SAMPLING PLANS & RELATED TOPICS

MIXING & SAMPLING WITH SPECIAL REFERENCE TO MULTI-SIZED GRANULAR MATERIAL; David Buslik, Chemical Engineer, Explosives Branch, Bureau of Mines, Pittsburgh, Pa.
(ASTM Bulletin, No. 165, April 1950, p. 66)

This paper derives a formula for the percent of a given size from random samples from a multi-sized aggregate. Consideration of the manner of arrangement of particles in such an aggregate and a discussion of mixing principles are also given.

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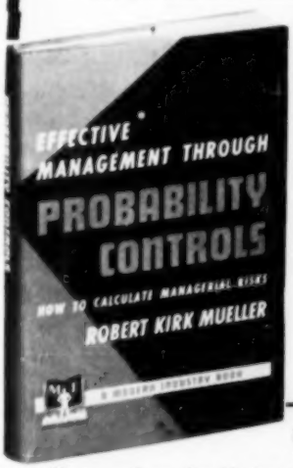

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THE FALLACY OF THE SQUARE ROOT SAMPLING RULE; J. Keith Borland
(Journal of the American Pharmaceutical Association, v. 39, n. 7, July 1950, p. 373)

Mr. Borland discusses the widely used plan of selecting the square root of the lot size as the sample size. Operating characteristics for a series of sampling plans using the square root system are presented. The inconsistency and weakness of the system is pointed out. Some explanation of the operating characteristics and the probabilities involved is given.

TRAINING & EDUCATIONAL

THE GROWTH OF STATISTICS & QUALITY CONTROL IN ENGINEERING COURSES; John A. Henry, Associate Professor of Mechanical Engineering, University of Illinois.
(Journal of Engineering Education, v. 40, n. 20, June 1950, p. 615)

A summary of the number of undergraduate students in engineering schools taking statistics or quality control, comparing the year 1949 to 1946. Undergraduate engineers taking quality control increased from 244 in 1946 to 2050 in 1949.

STATISTICS

BAYES & MINIMAX SOLUTION OF SEQUENTIAL DECISION PROBLEMS; K. J. Arrow and others.
(Econometrica, v. 17, July-Oct. 1949)

SOME ESTIMATES AND TESTS BASED UPON THE SMALLEST VALUES IN A SAMPLE: John E. Walsh, Rand Corporation.
(Annals of Mathematical Statistics, v. 21, n. 3, Sept. 1950)

ESTIMATING THE PRECISION OF MEASURING INSTRUMENTS; H. Fairfield Smith, Rubber Research Institute of Malaya.
(ASA Journal, v. 45, n. 251, Sept. 1950, p. 447)

ON THE CHOICE OF THE NUMBER AND WIDTH OF CLASSES FOR THE CHI SQUARE TEST FOR GOODNESS OF FIT; C. Arthur Williams, Jr., Columbia University.
(ASA Journal, v. 45, n. 249, March 1950, p. 77)

SAMPLE SIZE FOR ESTIMATING THE STANDARD DEVIATION AS A PERCENT OF ITS TRUE VALUE; Joseph A. Greenwood & Marion M. Sandomire.
(ASA Journal, v. 45, n. 250, June 1950, p. 257)

INTERFERENCE WITH A CONTROLLED PROCESS; Preston C. Hammer, Oregon State College.
(ASA Journal, v. 45, n. 250, June 1950, p. 249)

POWER OF THE CLASSICAL TESTS ASSOCIATED WITH THE NORMAL DISTRIBUTION; J. Wolfowitz.
(Annals of Mathematical Statistics, v. 20, Dec. 1949, p. 540)

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ELLIS R. OTT, Editor

A Circular Nomogram: Control Limits for p Charts

EDWARD C. VARNUM
Mathematician, Barber-Colman Company, Rockford, Illinois

TABLES of control limits for p charts can be found in statistics texts* corresponding to various sample sizes and various values of the fraction defective. Various nomograms have also been devised for this purpose, including one which was published in *Industrial Quality Control*, July, 1949, pp. 22-23. The accompanying circular nomogram is a companion to the Normal Curve Area Nomogram previously published in this journal.**

The nomogram presents values of

$$3\sigma_p = 3\sqrt{\bar{p}(1-\bar{p})/n}$$

for continuously varying values of n and $\bar{p}$ so that values for control limits can be found graphically rather than numerically. To use the nomogram, lay a straight-edge joining the sample size n on the upper semicircle and the fraction defective $\bar{p}$ on the diameter. The value of $3\sigma_p$ is then read on the lower semicircle.

In the figure, a sample size of 50 and a 2.8% fraction defective ($0.028 = \bar{p}$) lie on a line which crosses the lower scale close to the 7% index. The numerical calculation to obtain the value of $3\sigma_p$ is the following:

$$3\sqrt{(.028)(.972)/50}$$

$$= 3\sqrt{(.0272)/50}$$

$$= 3\sqrt{.000544}$$

$$= .069.$$

The nomogram can be used even when n is larger than the indicated 3000. For example, if n = 30,000 we first find $3\sigma_p$ corresponding to n = 300, which is .01 of the sample size. We then take .1 of this result to obtain the $3\sigma_p$ that corresponds to n = 30,000. Thus for $n = 30{,}000$ and $\bar{p} = .015$, we select n = 300 on the upper semicircle, $\bar{p} = .015$ on the diameter, and find .021 on the lower semicircle. The value of $3\sigma_p$ for n = 30,000 is then .0021 or 0.21%. The upper control limit is therefore .0171 and the lower control limit is .0129.

The accuracy of the nomogram is sufficient for its use with p charts and compares favorably with results obtained by a 10-inch slide rule. It is hoped that the nomogram will remove some of the tediousness of computing control limits for p charts and thus stimulate their industrial applications.

* Grant, E. L., *Statistical Quality Control*, McGraw-Hill, 1946, pp. 540-541.
** Varnum, Edward C., *Industrial Quality Control*, January, 1950, pp. 32-33.

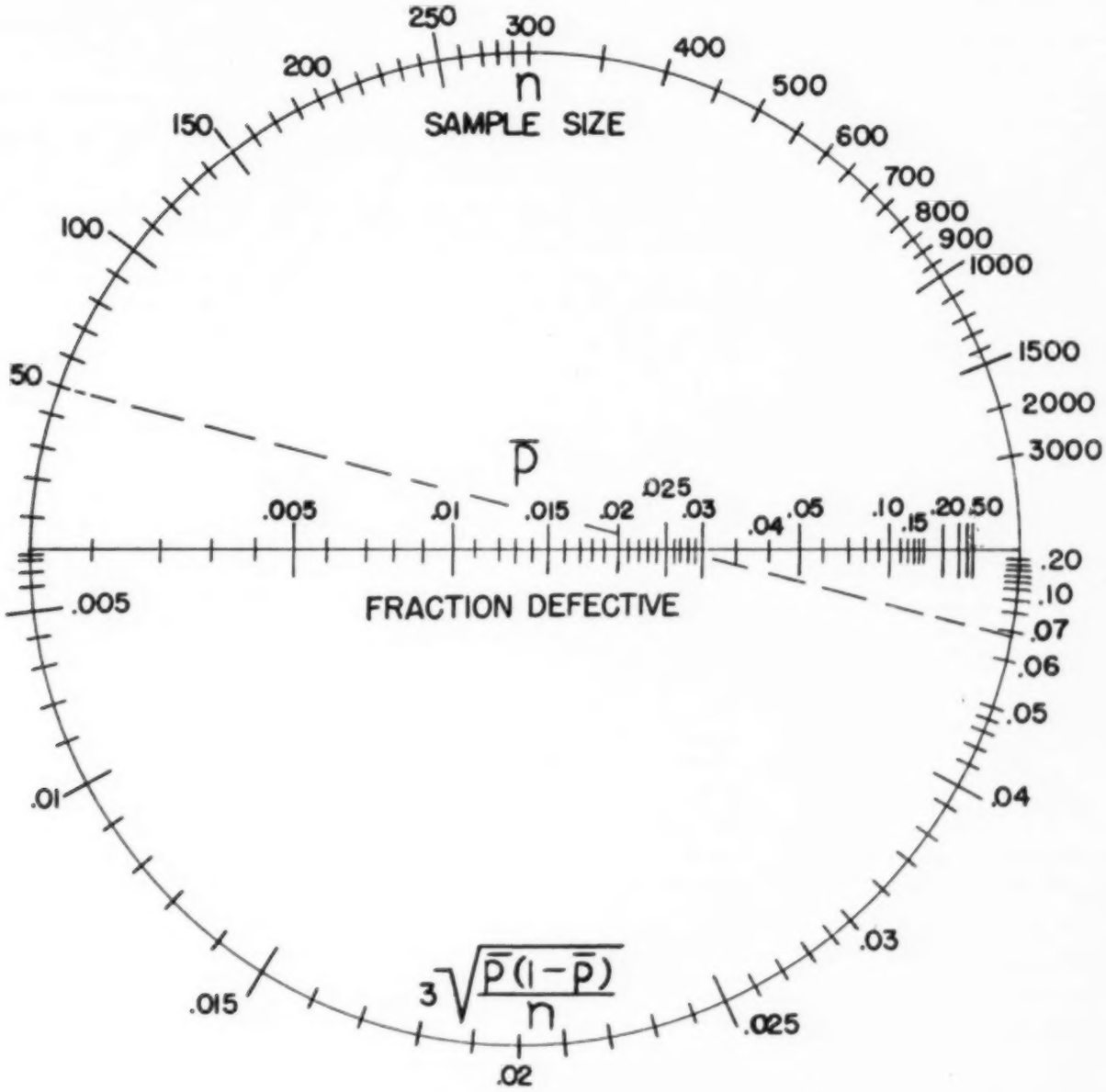
CONTROL LIMITS FOR P CHARTS

(SOLVING $3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$)

DIRECTIONS

Connect sample size n with fraction defective $\bar{p}$ and read $3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$ on lower scale.

Add and subtract this value from $\bar{p}$ to obtain upper and lower control limits.



EXAMPLE: IF N=50, $\bar{P}$=.028, DRAW A LINE FROM 50 TO .028 AS SHOWN BY BROKEN LINE, READ ANSWER=.069

U.C.L.=.028 + .069=.097

L.C.L.= .028 -.069=0. (L.C.L. IS NEVER NEGATIVE)

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A. C. Cohen, Jr., *Editor*

QUALITY CONTROL AND STATISTICAL METHODS

Edward M. Schrock; Reinhold Publishing Corp., New York, 1950. 213 + xi pp. Cloth. $5.00. Review by Louis C. Young, Department of Economics, Massachusetts Institute of Technology, Cambridge, Mass.

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University of Georgia
Athens, Ga.

Mr. Schrock's book on quality control and statistical methods is expressly intended for those who are new to the field, or relatively so. As such, it will serve to stimulate the interest of the reader in that it raises and answers many questions commonly asked by those who are newcomers to the field. Since the first half of the volume deals more heavily in direct application, leaving explanation of the statistical methods involved to the latter half, interest of the potential user of control methods is not likely to slow down until it has already had considerable encouragement.

The book has faults which will be detailed later, but these are largely statistical and pedagogical. They will not be objectionable to the novice to whom quality control is of indirect interest rather than a sole concern, nor will they be troublesome to one who has already had some fundamental training in statistical methods or appreciable experience in statistical quality control. Both of the latter will find the material broadening with regard to the applications listed and described. Indeed, Mr. Schrock provides a coherent outline of the purpose, nature, and method of quality control without retracing all the ground covered in earlier books on the subject, but with enlargement of the field by describing in detail some methods given scant attention by other authors. In this way, his book helpfully supplements others and could be placed to advantage in many company libraries.

With regard to content, the first thirty pages deal generally with the nature of quality and the economic objectives associated with it, and with the elementary means of presenting information pertaining to quality. In the following ninety pages are presented the applications of various types of control charts, with illustration and description of the details of use. The author then describes, in the course of about twenty pages, the various modifications of control limits which are usable wherever tool wear and similar factors of change are inevitable. Of the remaining fifty pages, Mr. Schrock devotes ten to probability distributions and significance of differences, thirty to a description of the nature of acceptance sampling (single, double, and sequential), and the last ten pages to correlation.

Comparing it with *Statistical Quality Control*, by E. L. Grant, one might say that it could be read completely with greater ease since it is less than one half the length of that text; its style, too, is directed more to the practical man than to the student. Although Schrock's book is more limited in general scope, it amplifies some subjects (for example, modified control limits) which receive only brief mention in the other. It has, on the other hand, greater coverage and detail than J. G. Rutherford's *Quality Control in Industry*, but lacks the latter's degree of analysis and discussion of the relationship between the quality control organization and other management functions.

The shortcomings of the book, from a statistical viewpoint, result from the deliberate attempt of the author to simplify the presentation of statistical methods to as great a degree as possible. Inasmuch as we can't have our cake and eat it, too, this has led to some implicit misrepresentation. For example, the author describes the application of three-sigma control limits in attribute control, without indicating the error or inadequacy of such approximate method in small samples and/or low fraction defective. He then gives fifty pages of tables of control limits (to eliminate the need for actual computa-

tion) based upon this same approximate method. The tables therefore have the virtue of confirming the formula previously given, yet might as easily have been (calculated and) presented more accurately by better approximation than that used. Since the approximate value is referred to, in this connection, as the theoretical value, the beginner might be led astray. This is of little importance, however, unless the beginner subsequently decides to pursue the subject further in other texts. In that case, some confusion might result. Some confusion might exist also in the vague distinction drawn between a parameter and a statistic, but this seems entirely excusable in the field of quality control where one progresses from sub-group to lot to grand lot to population. There are a few similar instances throughout the book, where more precise definition, in a broad sense, might well have detracted in interest more than it added in analysis.

It is well worth pointing out that Mr. Schrock's experience in the manufacture of refrigerators and allied products, together with background metallurgical knowledge, have given rise to a variety of technical problems covering many independent types of manufacturing operation. These are correspondingly reflected in the cases with which he has represented and illustrated the many applications of statistics to the control of quality. These are of particular interest in view of his own consideration of quality control, which is well expressed in the closing paragraph of his introduction, herewith quoted:

"Consider what scrap and rework cost you on an annual basis. Include in this what defective product costs you in terms of consumer good-will and reputation. Certainly you can afford to spend some portion of this amount to bring about a greater reduction in losses and an improved competitive position."

AMERICAN SOCIETY NEWS

NOMINATING COMMITTEE REPORT, 1951

The Nominating Committee has completed its work in selecting nominees for Society offices in 1951-52. The official report of the committee is reproduced herewith. All members of the Nominating Committee are members of the Board of Directors as provided in the Constitution.

December 1, 1950

Mr. Simon Collier
Executive Secretary, ASQC
New York, New York

Dear Mr. Collier:

As provided in the Constitution of the Society, we—the members of the Nominating Committee for 1950-51—do hereby report the following as our nominees unanimously chosen for the Society offices in 1951-52:

For President: Wade R. Weaver
Ohio Section

For Vice President: Simon Collier
Metropolitan Section

For Executive Secretary: Charles J. Hudson, Boston Section

For Treasurer: Paul A. Robert
Southern Tier Section

Each of the above nominees has expressed to our Chairman his willingness to accept if elected to the office for which we have nominated him.

Respectfully submitted,

Wilbur L. Burns
Ralph A. Hefner
Wyatt H. Lewis
Eugene H. MacNiece
A. C. Richmond
Dorian Shainin
Ralph E. Wareham, *Chairman*

TEXTILE TECHNICAL COMMITTEE

Members associated with the Textile field, and it has many ramifications, will be pleased to learn of the activation by the Society of a Technical Committee to cover this field.

Mr. W. S. Smith, Research Division of West Point Mfg. Co., Shawmut, Alabama, and Chairman of the Georgia Section, has agreed to head this Committee as Chairman. Due to the very broad field of interest involved and the numerous phases to be covered, the Chairman will be pleased to hear from members interested in working on this Committee.

COMMITTEE ON FOOD INDUSTRIES

In line with Technical Committee expansion programs, the Society has set up as a sub-committee of the Chemical Technical Committee a committee to cover the Food Industries field. All members interested in this activity are urged to contact Mr. Frank Kenney, Chief Chemist, White Rock Corp., 1 Park Avenue, New York, N. Y., who has been appointed by the President to act as Chairman.

EXECUTIVE COMMITTEE MEETS

The Executive Committee met in New York City on October 28-29 to review activity of the first quarter and to consolidate plans for the balance of the fiscal year.

The Executive Secretary's membership report was most encouraging. This showed 2,034 membership renewals, or 58% of last year's total, and 443 new members for a total of 2,477. This is 71% of last year's figure, as of record on October 27, 1950, and compares with a figure of 1,629 just a year ago; this latter figure is 62% of the previous year's total. It was of interest to note that those Sections presenting the best showing this year to date are, in general, those which have adopted the standard dues rate; billing was done for most of these Sections direct from National Headquarters.

The Treasurer's report showed that 71% of our anticipated income for the year had already been received as of October 27. This figure is also running ahead of expectations. A comparison of expenditures for the first quarter against budgeted amounts showed 29.76% of the budget to have been expended.

Decision was made to publish a Year Book; this is to appear as soon after January 1, 1951, as is possible from a mechanical standpoint. It will contain a complete roster of members as of record on December 31, 1950, as well as a complete listing of all Society Committees and the members comprising them. Due to the fact that the Constitution is somewhat in a state of flux, it was decided to have this document independently reproduced. The Year Book is planned to overcome certain criticisms of previous issues and to contain valuable additional information. A copy will be mailed to all members of record as of the mailing date.

There have been a large number of recent recommendations from our members on the establishment of additional Technical Committees. Your

Executive Committee wishes to move soundly on such matters but is fully aware of the situation confronting the Society. Decision was reached to establish a Textile Technical Committee, and several other industrial fields received considerable discussion but were deferred at this time.

Agreement was reached on the content of the March issue of IQC wherein exhibitors at the Fifth National Convention will be offered a space allotment of 150 words to describe their exhibit. Decision was also reached on the content of the May, or Special Convention issue.

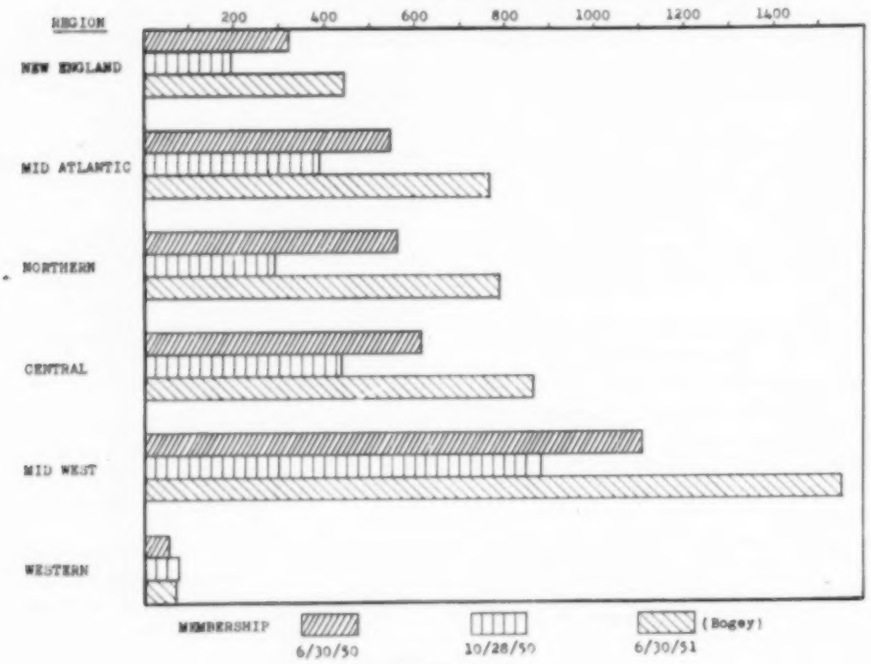
Two proposed new Sections of the Society, Parkersburg, W. Va., and Evansville, Ind., are well past the formative stages and it is expected that they will soon be a formal part of our growing family.

The Constitution has been redrafted to incorporate the changes approved by popular ballot on June 2, 1950, and the amended form will be reproduced and distributed to all Section Secretaries and National Directors.

A new printing has been made of both the General Information Folder and Membership application blank. These are now available upon request from the Executive Secretary. All Sections which have not already done so are urged to obtain a supply of these two new forms and use only these from now on. *It is important that all old forms be destroyed at once.*

BAR CHART OF ASQC MEMBERSHIP BY REGIONS AS OF JUNE 30, 1950 AND OCTOBER 28, 1950 WITH A BOGEY FOR JUNE 30, 1951 BASED ON A NATIONAL BOGEY OF 5,000 MEMBERS BY END OF 1950-1951 FISCAL YEAR

(Does Not Include Membership at Large or In-Training)



MEMBERSHIP

Total membership as of 10-28-50 was 2,477 or 71% of last year's total; however, 443 new members account for 18% of the total. Of the 3,510 members on record as of 6-30-50 only 58% or 2,034 had paid dues by 10-30-50 and therefore 42% became delinquent.

In the July issue, Mr. J. R. Steen, National Chairman of the Committee on Membership for 1949-50 fiscal year, proposed a goal of 5,000 corporate members by June 30, 1951. To attain this goal, each region must work for a 40% increase over last year's membership. The "Bogey Bars" in the chart above indicate the job ahead. What can we do about the loss of 42% of our membership through delinquency?

ROBERT S. INGLIS, *Chairman*, Committee on Membership

CONSULTING SERVICES

Responsibility of the American Society for Quality Control, Inc., for Consulting Services advertising is limited to certification that advertisers hold the grade of membership in the Society stated in their advertisements. Qualification requirements for the several grades of membership are set forth in the Constitution of the Society.

Management Controls

FOUNDED IN 1945

References and Literature on Request

Senior Partner: W. E. JONES
Fellow, ASQC

699 Rose Ave.
DES PLAINES, ILL.
DES PLAINES 1493

RALPH E. WAREHAM
Fellow, ASQC

CONSULTANT ON QUALITY CONTROL

122 ORCHARD RIDGE
CHAPPAQUA, N. Y.

TELEPHONE
CHAPPAQUA 715

POSITION AVAILABLE

MECHANICAL ENGINEER. If you possess experience in all types of inspection dealing with precision made, small forgings and finished parts, and if your work record included responsibility such as supervision, dealing with customers, organizing of departmental work, and if you possess the qualities of a good Administrator, there is an opening leading to Assistant to the Chief of Quality for a large Cleveland Manufacturer. Your reply should include all facts including past employers and earnings as well as salary requirements. Write to 7J1, American Society for Quality Control, 22 East 40th Street, New York 16, New York.

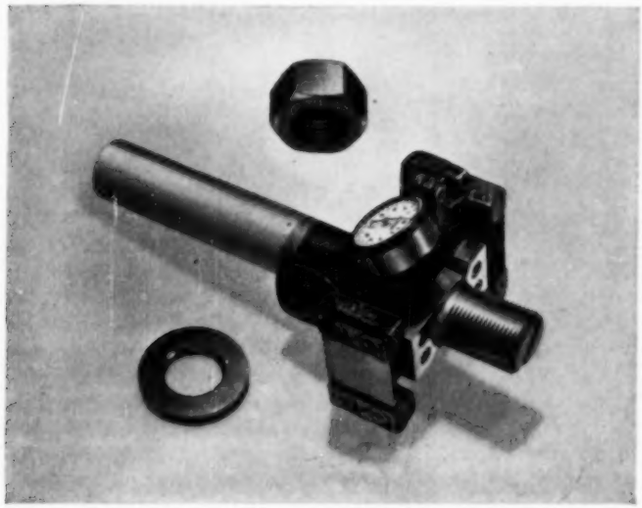
POSITION WANTED

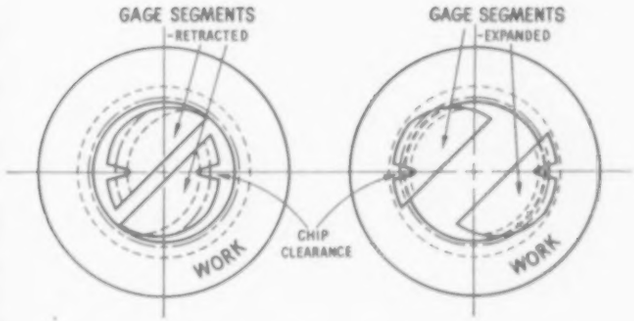
QUALTY CONTROL ENGINEER desires responsible position. Three years experience as supervisor of QC dept. 15 years experience in diversified manufacturing, Quality Control, Methods, Engineering, Time Study. Experienced in correlating quality concepts between Sales, Engineering, Manufacturing, and Customer. College graduate BS-ME. Age 38. Write to 7D1, American Society for Quality Control, 22 East 40th Street, New York 16, New York.

FOR SALE—INSPECTION EQUIPMENT

One Jones & Lamson Bench Optical Comparator
14" Diameter Screen—100X Optical System—Surplus Equipment
EXCHANGE
Surplus—Two 100X—One 62.5X—One 31.25X Optical Systems for 10X Systems
Contact — T. C. Entrikin
710 E. 14 St., N. Y. C.

The new Bryant Internal Thread Gage will check parts 4 to 5 times faster!





Plug segments are collapsed so gage may be inserted or withdrawn without threading.

Plug segments are expanded to give full length contact on all the threads.

The new Bryant internal thread gage is based on the principle of a split plug gage. The plug segments are collapsed by a thumb lever and inserted into the threaded hole. When the thumb lever is released, the plug segments expand to contact the internal threads in the parts being inspected.

This new gage is portable, therefore, threads may be checked while the part is chucked in a machine, and it offers extra convenience when inspecting threads in large, heavy casting that cannot be moved conveniently.

The Bryant gage is designed to give one accumulated reading of P. D., form and lead on the dial indicator. For the first time it is now possible to sort parts into known classifications for fit (assemble-ability). This gage is used for the inspection of internal threads in a range from 5/16" to 1" diameter. Interchangeable segments are easily attached to the gage to cover a wide range of thread sizes. These segments are made to the same tolerances in P. D., lead, and form as a Class "W" Master. The life of the segments is lengthened by the fact that the gage does not have to be screwed into or out of the threaded hole – a partial turn gives a full reading on all the elements of all the threads.

Actual tests show that the Bryant portable internal thread gage will check parts four to five times faster than the standard plug gage!

MAIL THE COUPON FOR FURTHER INFORMATION

COUPON

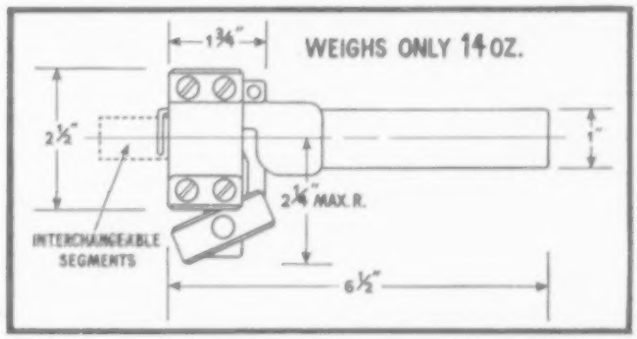
Please send me complete details on the New Bryant Portable Thread Gage.

NAME_____ TITLE_____

COMPANY_____

STREET_____

CITY_____ STATE_____

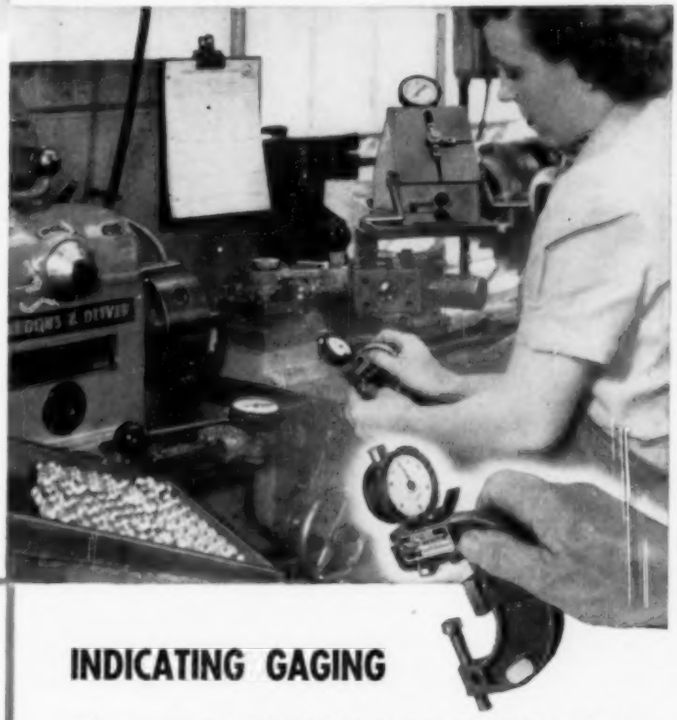


BRYANT

CHUCKING GRINDER CO.

SPRINGFIELD, VERMONT, U. S. A.

STOP "GUESS-GAGING"!

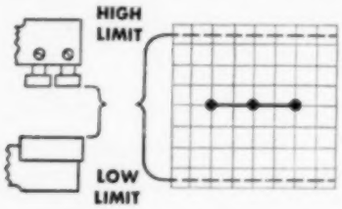


USE FEDERAL INDICATING GAGES AT PRODUCTION

If your machine operators wear that "guess-gaging" look, it's time to take a new look at your dimensional control gages. Old-type gages don't give your men a fair break. Ordinary snap gages, for instance, can't possibly warn machine operators when their machines are about to produce scrap. On the other hand, Federal Indicating Gages give your men the complete dimensional control they need to **prevent scrap.**

"GUESS-GAGING"

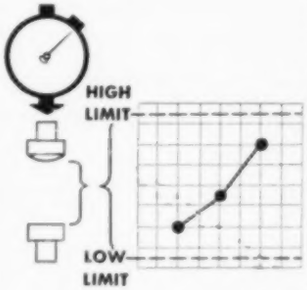
Checking parts coming off the machine with a "go, not-go" gage, the operator has to guess on borderline cases — that's to be expected with this type of gage. He simply knows each part measures within tolerances. No indication is given of tool wear, machine adjustment changes, or other conditions which will cause scrap.



If the operator finds too many parts are over or under size, he resets his machine or regrinds his tools, bringing production back within tolerances. But the damage has been done. The operator has produced scrap because he was penalized by "guess-gaging" dimensional control equipment.

INDICATING GAGING

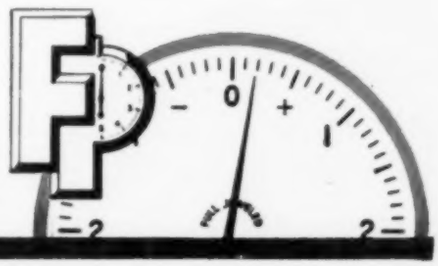
When you put a Federal Indicating Gage in the hands of this same operator, he doesn't guess-gage because he *sees* exactly what each workpiece measures. In this case he sees a *trend.*



Obviously something definite is happening, because the Indicating Gage shows the diameter is steadily becoming larger. Something has to be done about it. The operator makes his machine and tool adjustments *now . . . before* it's too late . . . *before* scrap is produced.

There's no guess-work about it with the Federal Indicating Gage. The operator knows his production is right — he can see it clearly on the Dial, beyond the shadow of a doubt.

Federal has pioneered in the development, design, and manufacture of Indicating Gages of all types — mechanical, electrical, electronic, and air. If you are modernizing your dimensional control equipment, be sure to consult Federal. No obligation. FEDERAL PRODUCTS CORPORATION, 151 Eddy Street, Providence 1, R. I.

FEDERAL

Largest manufacturer devoted exclusively to designing and manufacturing *all types* of DIMENSIONAL INDICATING GAGES